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THE ROLE OF FIRE IN PONDERODA PINE AND MEXED CONIFER ECOSYSTEMS

by

Jack S. Barrows et al.

THESES AND REPORTS

Final Report

THE ROLE OF FIRE IN PONDEROSA PINE AND MIXED CONIFER ECOSYSTEMS[1]

by

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I. INTRODUCTION

The Historic Role of Fire.

Fire is an agent of change in many wildland ecosystems. For centuries the general characteristics of forest and range ecosystems have been influenced by wildfires. The historic evidence of forest fires reveals dynamic and often large scale impacts on vegetation complexes and the mosaics of mountain landscapes. Fire scars in Colorado forests show that large fires occurred in the mountain regions of the state in 1676, 1707, 1722, 1753 and 1781 (Brown and Davis, 1973). Fire continues to play an active role in Colorado forests. During the period 1960-1975 more than 17,000 fires occurred on all protected state, private and federal lands (U.S. Forest Service 1960-1975).

Ponderosa pine and mixed conifer ecosystems are especially influenced by fire. Many early explorers in these forest regions of the west reported evidence of fires nearly everywhere. Our studies in Rocky Mountain National Park and the Arapaho-Roosevelt National Forests revealed fire scars and charcoal to be common phenomena. Tree scar studies indicate fire dates as early as about 1566. Within the ponderosa pine zone of the national park and national forests an annual average of 16 wildfires occurred in the ponderosa pine zone of these areas during the ten-year period 1960-1969.

In the ponderosa pine and mixed conifer forests fire impacts both ecosystems and society. Forest ecologists have observed that these vegetation complexes are adopted to periodic burning (Weaver, 1974). Frequent low intensity fire perform a multiple role of surface fuel reduction, thinning of understory trees, and herbaceous vegetation, exposure of some mineral soil and recycling of nutrients. The overall fire effects are influenced by complex interactions of many factors including stand age and condition, species composition and fire periodicity, intensity, size and season of burning. Societal effects are related directly to resource management objectives for an area, economic factors of forest resource use and the safeguarding of human lives and property.

Knowledge of the historic role of fire is essential in the development of strategies to meet specific management objectives. History shows that several fires have swept over hundreds of thousands of acres of ponderosa

pine forests in the west (Harlow and Harrar, 1941). Resource managers need to seek a safe, balanced approach that utilizes the ecological processes of fire while at the same time safeguards society from potential damages of fire. Assistance in developing some of the needed fire and ecological information to answer the complex questions involved is the main thrust of this research project.

Fire in the Front Range Forests of Colorado

The specific sites for this research of the role of fire in ponderosa pine and mixed conifer ecosystems are in Rocky Mountain National Park and the Arapaho-Roosevelt National Forest. It is useful, first, to examine the general forest fire situation along the Front Range of Colorado and specifically in the ponderosa pine zone.

Detailed fire history is available from thousands of individual fire reports from the five national forests situated along the Front Range. During the period 1960-1973 a total of 2336 fires burned 13,374 acres in these national forests. The average annual occurrence during this period was 25 fires per million acres. The average annual area burned was 955 acres per million acres protected. Lightning caused 46 percent of the fires and 13 percent of the area burned (Ryan, 1976).

In the Front Range national forests there are approximately 503,000 acres of commercially valuable ponderosa pine. This forest type has the greatest fire load in the region. During the 1960-1969 period 664 fires burned 3755 acres in the type. This amounted to 42 percent of the fires and 26 percent of the area burned in all forest types of the Front Range. The average annual fire ignition rate in ponderosa pine was 132 fires per million acres or more than four times greater than the average for all cover types. The average annual occurrence of class C or larger fires (10 or more acres in size) was 3.4 fires per million acres as compared to only 1.0 for all cover types (Ryan and Barrows, 1975).

The ponderosa pine forests are the scene of the greatest density of lightning fires in the Front Range. During the 1960-1973 period an annual average of 82 lightning fires per million acres occurred in this type as compared to only 13 lightning fires in all cover types. In ponderosa pine 62 percent of the

fires are lightning caused. It is interesting to note that Douglas fir, the major forest type of the mixed conifers associated with the ponderosa pine zone, also had a high lightning ignition rate of 61 fires per million acres. Both types are concentrated in the elevation zone of 7500 to 8500 feet above sea level (Ryan and Barrows, 1975).

This general overview of fires in Front Range forests and especially of the ponderosa pine zone provides a benchmark for studies of the role of fire in Rocky Mountain National Park and the Arapaho-Roosevelt National Forest.

II. RESEARCH OBJECTIVES AND METHODS

Objectives

The objectives of this research have been to develop the knowledge and technology required for the establishment of a fire management strategy compatible with overall natural resource management objectives for the ponderosa pine and mixed conifer ecosystems. The studies have been directed towards defining the role fire plays in these areas. The approach has been to determine the fire history of these ecosystems, to determine the ecosystem response to fire, and to determine the characteristics of prescribed fires at selected sites. A final objective of the project has been the preparation of a fire information base and recommendations for development of fire management strategies.

Methods

Two independent studies were involved in determining the fire history of the ecosystems. Prehistoric and historic fires were analyzed separately. Recent fire history was ascertained through analysis of individual fire reports maintained by the Arapaho-Roosevelt National Forest and Rocky Mountain National Park (Ryan and Barrows, 1975). The examination of these written records was designed to indicate the relative importance of many fire parameters, including causes, fuels, size classes, and periods of occurrences.

Fire history prior to the establishment of the National Park and Forest was determined through studies of tree rings obtained from selected fire scarred trees. During the 1975 field season 22 scarred trees were felled within Rocky Mountain National Park. Cross-sections were taken from the lower boles of these sample trees and analyzed to determine the occurrence and frequency of fire events, recorded as scars during the life of the trees (Housten, 1973). The locations of these felled trees were mapped and became the sites for some of the ecosystem response studies.

The determination of ecosystem response to fire was also conducted as two separate studies. Short-term responses were based upon pre- and post-fire inventories conducted at the sites of prescribed fires. Vegetation and fuel characteristics of the sites corresponding to the 22 sample fire

scarred trees were utilized to determine the long-term ecosystem responses.

A total of 12 distinct sites were recognized from the 22 felled trees. During the 1976 field season inventories of both the boitic, excluding fauna, and abiotic components of the ecosystems were conducted. The stump, or midpoint if two trees composed a single site, was designated as the sample point from which the inventories were conducted. A modified version of the Braun-Blanquet Relative Density technique was used to define the vegetation characteristics at each site (Clagg, 1975). Four sets of three concentric circular plots were established at 0, 90, 180, and 270 degrees and centered at a distance of 10 meters from the primary sample point (stump). The circular plots were 1, 5, and 20 milacres. Within the 1 milacre plots frequencies and relative densities were determined for forbs, grasses, and sedges. Shrub and tree seedling (less than three feet tall) parameters were determined within the 5 milacre plots, and tree and snag (standing dead tree) densities and frequencies were tallied within the 20 milacre plots (Figure 1). Density values for seedlings, trees, and snags were expressed as the number of stems per acre. A count of the individual shrubs was also made. However, shrub and lesser vegetation densities were classified by relative abundance categories. The four possible relative abundance categories used were as follows:

Abundant - found everywhere in the plot to the exclusion of most other species.

Common - found everywhere in the plot, but in company with other species.

Occasional - found several places in the plot, but not dominant

Rare - only one or two specimens in the plot.

The vegetation inventories were used to examine the floral characteristics of these sites in relation to their fire histories. While the relative abundance values of densities can not be considered as definitive as those from other possible inventory procedures, they do adequately serve the study objective with respect to the comparative values of the existing vegetation.

An inventory of the fuels was also conducted at each research site to determine the fuel bed characteristics and the fuel loadings for downed woody

material (by size classes), herbaceous vegetation (grasses and forbs), and the forest floor (litter, duff, and cones). The inventory procedure used for downed woody fuels and cones was the planar intersect technique developed by Brown (1974a). The method of inventorying the herbaceous vegetation and litter was the relative-estimate technique (Brown, 1974b). Figure 2 illustrates the fuels inventory design. These fuel inventory procedures were the basis for investigating fuel accumulations with respect to fire history and have aided in evaluating the probable fire behavior characteristics of each site.

Physical site factors were also determined at each location. Common hand-held field equipment was used to evaluate slope aspect and percent rise, site index, and basal area per acre. The position of each site on its slope was determined by observation, as was the forest stand structure and condition (single or multiple-storied stand, crown class and ratio, tree history or damage from insects, winds, animals, etc.). Characteristics of the soils were noted (Fullinwicker and Shaw, 1971) and the elevation of each site was determined from topographic maps. These physical site factors have been important in evaluating the vegetation and fuel inventories.

Pre- and post-fire inventories at the Eagles Cliff (1975) and Mill Creek (1976) prescribed fires were the basis for evaluating the short-term ecosystem responses to fire. As with the older fire sites, vegetation and fuel components were inventoried. In addition, organic and important inorganic soil nutrient levels were measured at the Eagles Cliff site.

Soil samples were taken at a depth of 4 and 20 centimeters below the surface at 13 locations just prior to ignition of the Eagles Cliff research fire. These depths were selected to determine the extent of movement of chemical elements released by the fire. One year after the burn these same 13 locations were resampled using the pre-fire inventory procedures. Soil samples were taken to the Soil Testing Laboratory on the Colorado State University campus and the nutrient analysis was carried out by their technicians. The soil information has been useful in the interpretation of the early vegetation responses on the site.

The vegetation and fuels inventory procedures conducted at the prescribed fires sites were essentially the same as those described in relation to the

long-term fire effects studies. The modified Braun-Blanquet Relative Density system was employed in the vegetation samplings and the techniques developed by Braun were used to inventory the fuels. Sampling designs for all of the Mill Creek fire studies can be seen in Figures 1 and 2.

While the inventory procedures were basically the same at the Eagles Cliff site, the intensity of sampling did vary from year to year. Prior to ignition, 45 plots were established at the Eagles Cliff site. During the pre-fire inventories the relative abundance scheme was employed to the vegetation, but only a single set of concentric plots, centered about the point, was used. During the two subsequent field seasons, four sets of circular plots were generally used at each point inventoried. To assure consistency on the sampling, one of the four "subplots" was randomly brought in to cover the point center. Figure 3 depicts this design. Similarly, the initial fuel inventory transect lines were 30 feet long. Later procedures slightly reduced the total number of transect lines but increased the length of those retained to 50 feet.

The pre- and post-fire inventories carried on at the prescribed fire sites were essential to the short-term fire effects studies. Unlike research concerned with older fires, these studies have enabled the ecosystem responses to be evaluated in relation to quantified fires of known intensities and behavior.

To allow for the continuation of studies at the two precribed fire sites, the sample points established prior to the burning have been pinned, flagged, and mapped. Magnetic bearings and the distance between the plots were also recorded.

In addition to evaluating short-term fire effects on the ecosystems, the prescribed fires were designed for the analysis of fire behavior parameters (rate of spread, fireline intensity, flame duration, depth of burn in soil, crown scorch height). Other objectives of the prescribed fire studies were the evaluation of the fire prescriptions and the burning techniques employed, and as data input into the development of fire management strategies.

Computer-based models for predicting wildland fire behavior (Albini, 1976) were used to provide input for prescribed fire planning, and in the development and testing of burning prescriptions to meet specified research

and resource management objectives. The burning prescription defines the following:

Date
Time of Day
Precipitation
Range of Temperature and Relative Humidity
Wind Direction and Velocity
Atmospheric Stability
Fuel Condition and Moisture
Weather Forecast

The research and resource management objectives specified determined the type of fire (head, backing, flanking, or perimeter fire) and the burning presciption parameters used for the prescribed fire.

Inputs to the fire behavior models were fuels (type, amount, physical and chemical properties, and moisture), weather (precipitation, temperature, relative humidity, and wind velocity), and topography (slope steepness). The fire behavior models provided predicted values for the linear rate of fire spread, perimeter and area growth rates, Byram's fireline intensity, total energy released, flame length and crown scorch height, and the degree of fuel consumption and time history of fire intensity in heavier fuels.

A fire behavior analysis was completed for each prescribed fire. The fire behavior analysis was composed of three parts: (1) site description, (2) fire behavior measurements, and (3) fire description.

The site description included the fire location, fuel type, and important topographic features. Fuel moisture samples of the dominant fuel types and weather observations (such as temperature, relative humidity, wind velocity and direction) were recorded every hour.

The fire behavior measurements made included the linear rate of spread, flame length and duration, Byram's fire line intensity, and total energy release. Aerial fire characteristics such as number of crowns scorched, crown scorch height, and percent of crowns scorched were also recorded.

The fire description section included the type of fire (ground or aerial fire and its characteristics), fuel involvement, and spread continuity.

FIGURE 1

"Design of Braun-Blanquet Relative

Densitivity inventory technique."

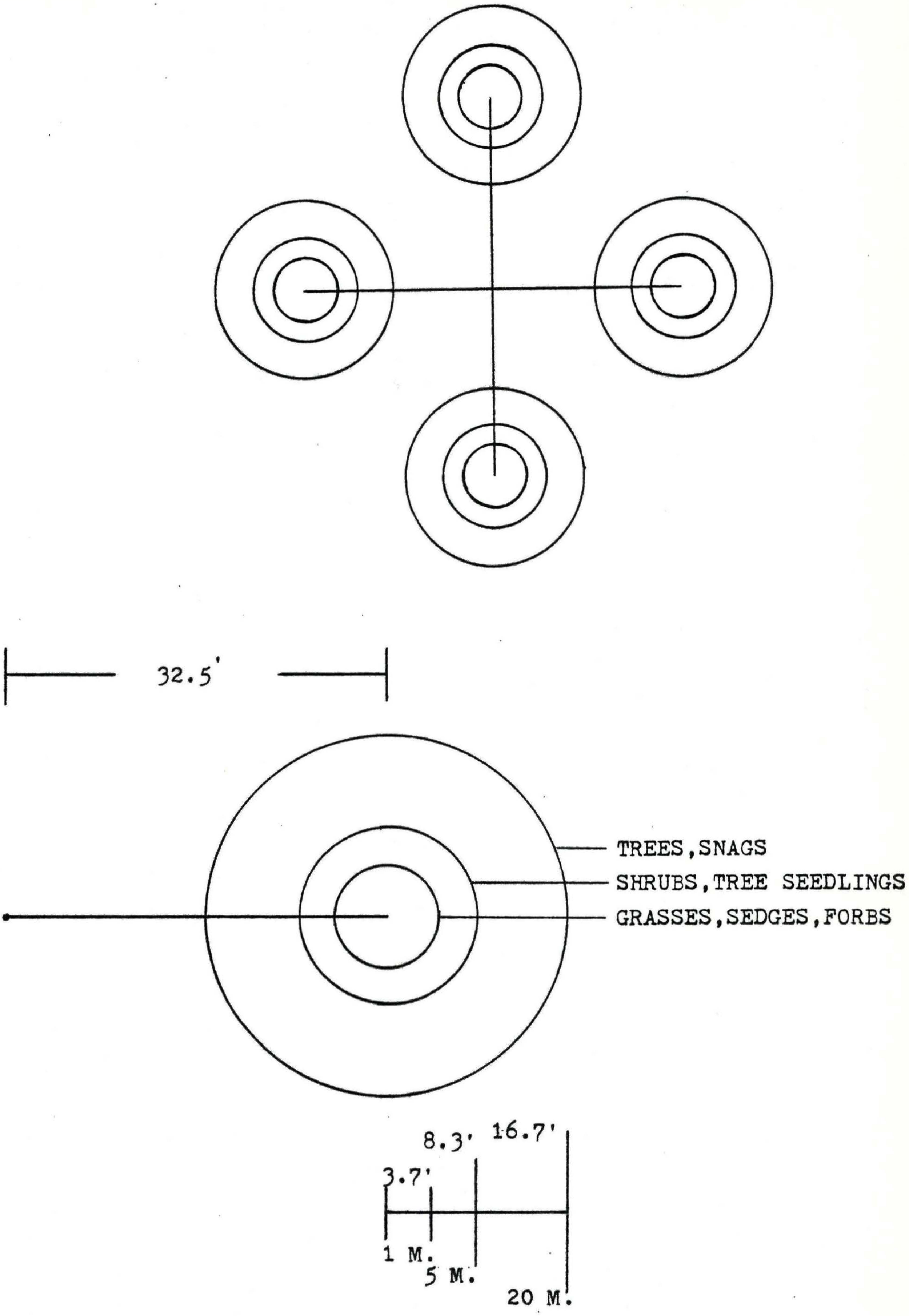
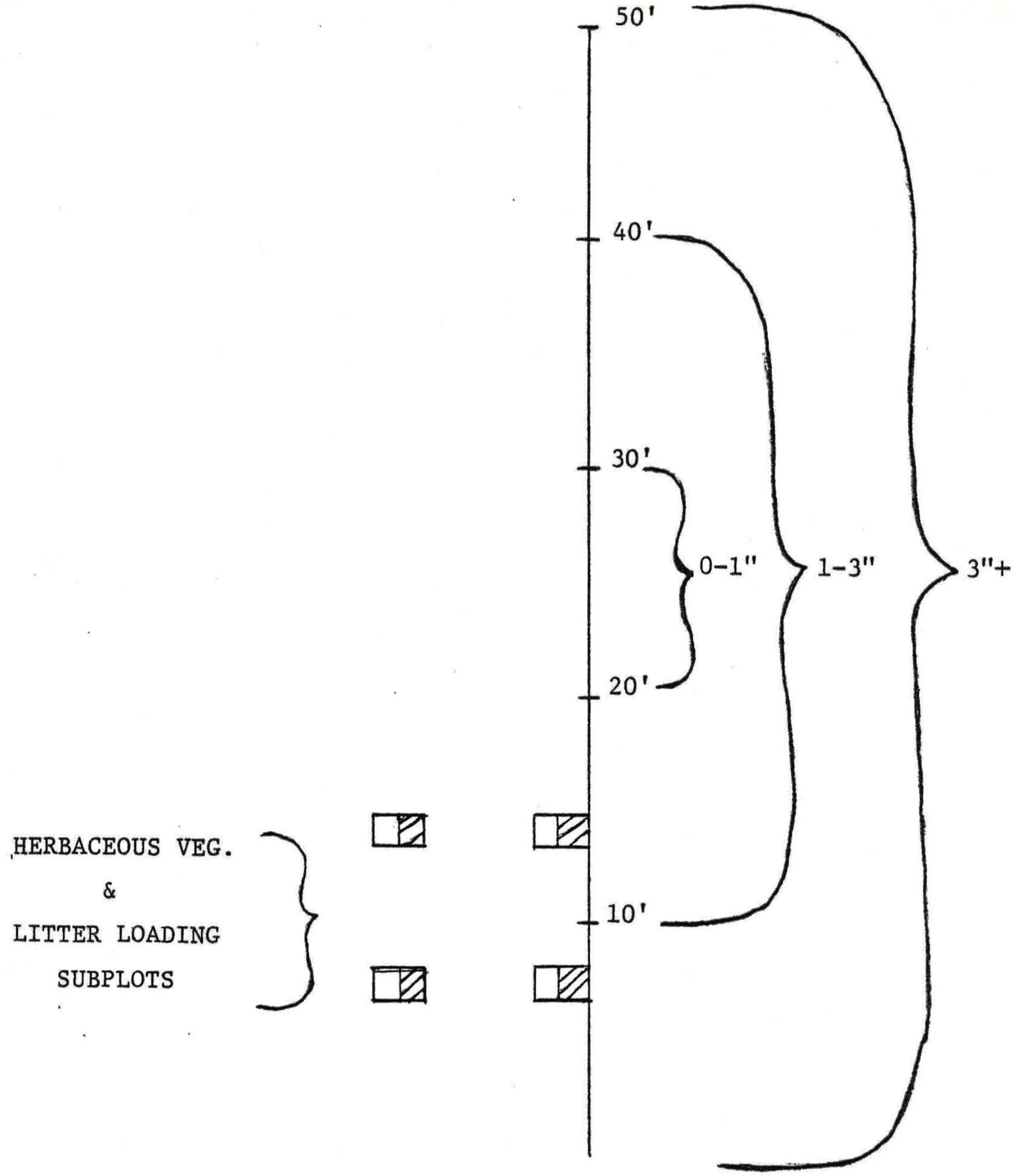

32.5'
TREES, SNAGS
SHRUBS, TREE SEEDLINGS
GRASSES, SEDGES, FORBS
3.7'
8.3'
16.7'
1 M.
5 M.
20 M.

FIGURE 2

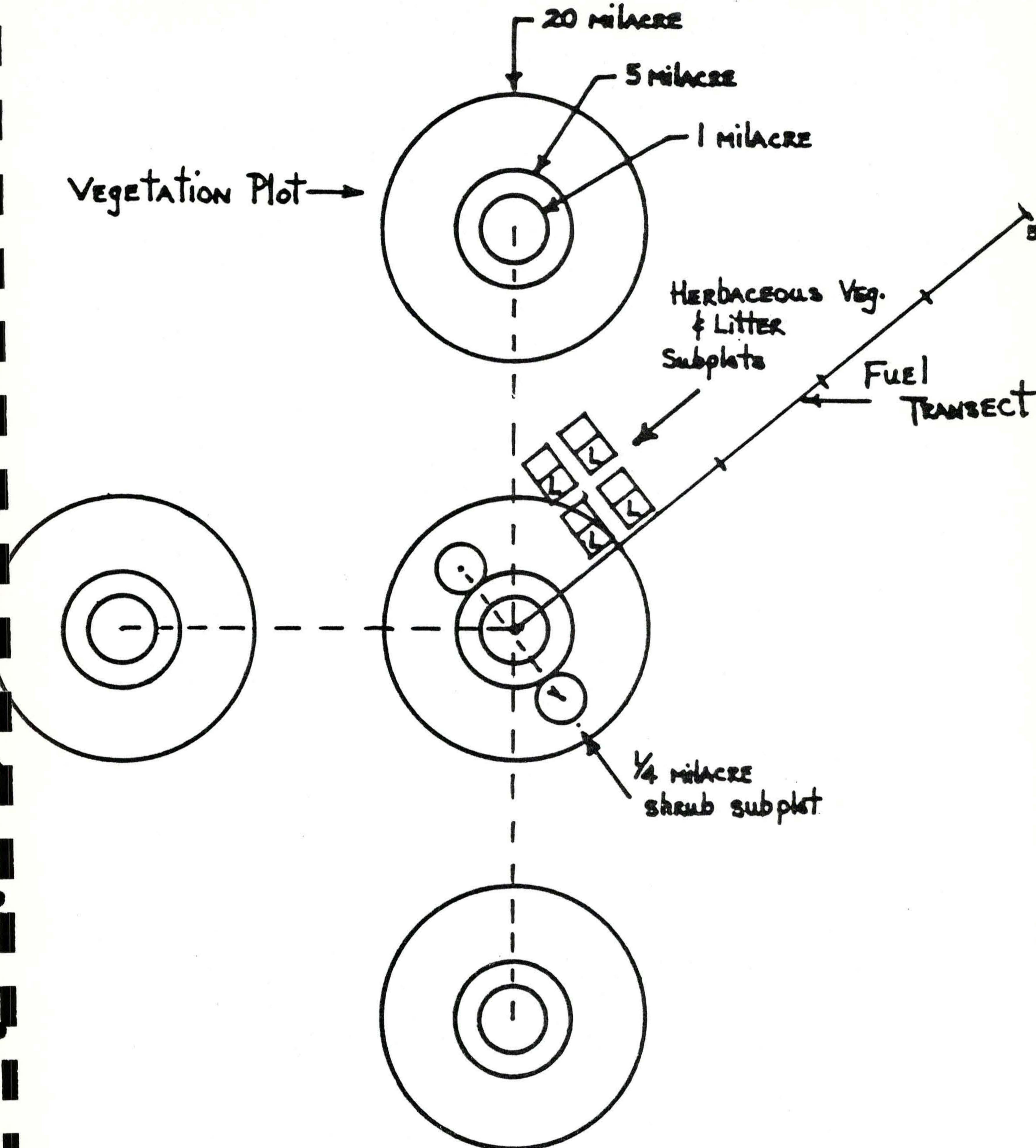
"Design of the Planar-Intersect technique for inventory of downed woody materials and surface fuels."



FUEL DEPTHS	DISTANCE (Ft.) ALONG TRANSECT	
DEAD LIVE	0, 10, 20, 30, 40, 50	
LITTER		quadrats 1-4
DUFF		" "

FIGURE 3

"Sampling design employed at Eagle's Cliff prescribed fire site during the 1976 and 1977 field seasons."



Sample Point Design

III. WILDFIRE HISTORY

Short-term Fire History

For the alter observer, even a casual stroll through the study area would be sufficient inspection to recognize fires past existance in the system. Charcoal and burned limbs scattered along the forest floor, many older trees bearing fire scars, and the sharp changes in stand structures serve as the ever-present testaments to fire's history in the area. However, if the role of fire in this environment was to be defined more precise information was needed and an analysis of the available fire reports, maintained by the National Park Service and U.S. Forest Service, was conducted first to evaluate fire parameters for the area.

Although evidence of past fires is frequently encountered in the study area, upon review of the fire reports it was immediately apparent that fire occurrence and the number of acres burned have been relatively low in recent years. During the 20-year period of 1954 through 1973 only 48 fires were recorded in the park service's file for the montane zone. Comparisons with complementary statistics (1960-1969) for all other Colorado Front Range Forests indicate the study area experiences considerably fewer fires than its immediate surroundings (Table 1, Ryan and Barrows, 1975). Only on the adjacent Arapaho National Forest, where the ponderosa pine cover type is restricted to a few isolated areas, are the figures lower. In the surrounding Roosevelt National Forest the number of fire ignitions is five and one-half times greater than that for the study area.

Further analysis revealed that approximately 80 percent of the fires occurring in the national park were man-caused, and that only 10 fires reported in the 20-year study period were started from lightning. This indicates a recent national fire occurrence of 1 fire every 2 years for the study area. In addition, about 80 percent of all reported fires were class A (.25 acres or less) burns, with only a single fire burning in excess of 10 acres during the study period. This single man-caused fire in 1966 consumed 78 acres and accounts for nearly 80 percent of the total acreage burned during the entire 20 years. The records also show that most fires occur during the summer month, July in particular, but that fires have started at almost any time of the year (Table 2). Seventy percent of the fires in the zone burn primarily in

forest fuels (mature trees, understory, surface debris), while grass (20%) and brush (10%) account for the remainder.

The most significant information gained from the fire reports was, however, the apparent very low occurrence of natural fires in the area. It may be postulated that the widespread evidence of fires indicates: 1) the occasional occurence of very large fires prior to fire control efforts, probably ignited in the lower forest lands adjacent to the park; or 2) the occurrence of large numbers of lightning fires not apparent in the short time period represented by the available fire reports. The prehistoric records contained within the ecosystem itself were considered the key to better understanding fires primeval role in this environment.

Table 1. Number of Fires and Area Burned for Ponderosa Pine Cover Type in Colorado front range, 1960 - 1969.

	Rocky Mt. Nat. Park	Arapaho	Pike	Rio Grade	Roosevelt	San Isabel	Total
Number of Fires	25	3	407	32	141	81	689
Area Burned	95	23	3163	7	464	98	3850

Table 2. Fire occurrence in Rocky Mountain National Park by ignition source and time of year, 1954-1973.

Cause	Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Man	2	1	1	2	1	5	12	4	4	3	0	1	36
	Lightning	0	0	0	0	1	1	8	0	0	0	0	0	10
	Unknown	0	0	0	0	0	1	0	0	1	0	0	0	2
	All	2	1	1	2	2	7	20	4	5	3	0	1	48

Long-Term Fire History

To determine the periodicity and extent of fire occurrence in the ponderosa pine and mixed conifer ecosystems prior to written records 22 fire scared trees were felled within Rocky Mountain National Park. Cross sections were removed from the bases of these sample trees, dried, and examined to determine the fire events in the life of each tree.

Species makeup of the 22 trees were 18 ponderosa pines, 2 Douglas-firs, and 2 lodgepole pines. The oldest tree was established in 1492, the youngest in 1863, and the sample trees ranged in age from 112 to 483 years at the time of cutting (1975). Average age for the trees was 277 years. A total of 69 fire scars were found on the 22 trees, with one to seven scars per tree. The arithmetic mean was nearly three scars for each tree. The fire record obtained from these trees spans the last 388 years from 1975 to the earliest recorded event, dated 1587, with the last scar resulting from a fire in 1940. Fifty-one intervals were also recognized. The average number of years between recorded fires was 40 and ranged from 4 to 141 years.

Subjective analysis of those early results shows a high concentration of events between 1840 and 1880 which coincides with the period of settlement in the area (Figure 4). After fire suppression activities were begun in the Park in the early 1900's a marked decrease in the number of fire scars is also seen. The period before settlement is believed to depict the most natural pattern of fire for the area. The record also shows a good correlation with the commonly identified high fire event years for the ponderosa pine zone of the Front Range: 1676, 1707, 1722, 1753, and 1781 (Brown and Davis, 1973).

The initial tree ring studies were designed to identify the fire history of the ponderosa pine zone within the Park as a whole. To satisfy this objective the analysis was based upon 10 geographic "subzones" which were recognized from the 22 sample tree locations. Following established procedures (Housten, 1973) the mean interval between fires for each individual tree was first determined. Then an average mean interval between fires was calculated using

$$\bar{\bar{X}} = \frac{\Sigma(Y/S)}{N_t}$$

where: Y is the age of the tree

S is the number of fire scars for that tree

N_t is the total number of trees

Results of this analysis (Table 3) indicate an average fire frequency of 110 years for the entire zone. "Adjusted" mean intervals were then calculated by substracting 60 years from the sample tree ages to asses fire frequencies prior to the suppression activities of modern man. The mean fire frequency was reduced to 84 years by this procedure and ranged from 28 to 165 years on an individual tree (geographic subzone) basis.

Subsequent analysis of the data was designed for investigating long-term responses to fire. This was accomplished by grouping the data into 12 distinct ecosystems. The data was again inspected using Houston's techniques (Table 4). The adjusted mean interval between fires for these sites was 90 years. However, the vegetation and fuels presently encountered at these sites are the products of suppression activities and for this reason it was more appropriate to view these fire frequencies in terms of the nonadjusted values. Fire frequencies for the 12 sites ranged from 29 to 225 years with an arithmetic mean of 116 years between fires.

When considering the tree ring studies it must be remembered that the record obtained from the sample trees, while the best available, is incomplete. The actual year of a fire, recorded as a scar, may be in error by at least $\pm$ 2 years due to resin deposits, insect damage, or decay and the choice of the fire annulus is somewhat arbitrary. Further, it is not known what exact fire and tree parameters are involved in the formation of a scar. Certainly an extremely intense fire would have destroyed a tree and its record would be lost; while a light fire may fail to be recorded by a healthy tree. It is true, however, that if there is a fire scar then the tree did experience a fire. For these reasons the long-term fire history record must be considered a conservative estimate of the realities.

FIGURE 4

"Fire chronology for the study area

based on tree ring analysis"

Deer Ridge	Deer Mtn.	Tmpsn Park	Lumpy Ridge	Lily Mtn.	Bighorn R.S. Horseshoe Park			Beaver Meadows			Eagle Cliff				South Lateral Moraine Hollowell Park					Tuxedo Park		Location
14	13	9	19	18	17	16	15	10	12	11	23	22	21	8	7	6	5	4	3	2	1	Tree No.
1846 1842 1658	1870 1750	1940 1922 1882 1875 1862 1809 1746 1728	1855 1807 1747 1706 1561	1873 1862 1721	1877 1866 1855 1786	1875 1846 1783	1875 1843 1734	1930 1917 1873 1851 1827 1777	1918 1899 1861 1841 1811 1758	1864 1855 1810 1791 1740	1833 1759 1643 1567 1492	1899 1851 1807	1901 1855 1816	1868 1846 1798 1739 1719 1680 1672 1615	1862 1799 1742 1523	1866 1804 1688	1867 1763	1892 1863	1900 1862 1721 1634	1843 1794 1617	1855 1814 1726 1712 1687 1676 1630	1940 1920 1900 1880 1860 1840 1820 1800 1780 1760 1740 1720 1700 1680 1660 1640 1620 1600 1580 1560 1540 1520 1500 1480

TABLE 3

"Summary of fire scarred tree data."

Table 3. Summary of Fire Scarred Tree Data in the Ponderosa Pine Zone of Rocky Mountain National Park.

Location	Tree No.	Year Estab.	Tree Age	No. of Scars Per Tree	Periods Between Fires in Years	No. of Periods	Tree Age ÷ No. Scars	Tree Age - 60 Yrs. ÷ No. of Scars
Tuxedo	1 PP	1630	345	6	41,88,14,25,11	5	57.50	47.50
Park	2 PP	1617	358	2	49	1	179.00	149.00
Total			703	8	228	6	236.50	196.50
No.			2	2	2	2	2	2
Ave.			351.5	4	114	3	118.25	98.25
	8 PP	1615	360	7	22,48,60,20,39,8	6	51.43	42.86
Eagle	21 PP	1816	159	2	46	1	79.50	49.50
Cliff	22 PP	1807	168	2	48	1	84.00	54.00
	23 PP	1492	483	4	74, 116, 56	3	120.75	105.75
Total			1170	15	537	11	335.68	252.11
No.			4	4	4	4	4	4
Ave.			292.5	3.75	134.25	2.75	83.92	63.03
Beaver	10 PP	1777	198	5	13,44,22,24	4	49.50	34.50
Meadows	11 PP	1740	235	4	9,45,20	3	58.75	43.75
	12 DF	1758	217	5	19,38,20,30	4	43.40	31.40
Total			650	14	284	11	151.65	109.65
No.			3	3	3	3	3	3
Ave.			216.67	4.67	94.67	3.67	50.55	36.55
Bighorn RS	15 PP	1734	241	2	32	1	120.50	90.50
Horseshoe	16 PP	1783	192	2	29	1	96.00	66.00
Park	17 PP	1786	189	3	11,11	2	63.00	43.00
Total			622	7	83	4	279.50	199.50
No.			3	3	3	3	3	3
Ave.			207.33	2.33	27.67	1.33	93.17	66.50
South	3 PP	1634	341	3	38,141	2	113.67	93.67
Lateral	4 LP	1863	112	1	29	1	112.00	52.00
Moraine-	5 PP	1763	212	1	104	1	212.00	152.00
Hollowell	6 PP	1688	287	2	62	1	143.50	113.50
Park	7 PP	1523	452	3	63,57	2	150.67	130.67
Total			1404	10	494	7	731.84	541.84
No.			5	5	5	5	5	5
Ave.			280.80	2	98.80	1.40	146.37	108.37
Lilly Mtn.	18 PP	1621	354	1	11	1	177.00	147.00
Lumpy Ridge	19 PP	1561	414	5	48,60,19,22	4	82.80	70.80
Thompson Park	9 DF	1746	229	6	18,40,7,13,53	5	38.17	28.17
Deer Mtn.	13 PP	1750	225	1	120	1	225.00	165.00
Deer Ridge	14 PP	1658	317	2	4	1	158.50	128.50
TOTAL			6088	70	2041	51	2416.64	1839.07
AVERAGE			276.73	3.18	40.02		109.85	83.50

TABLE 4

"Analysis of tree ring data based on Houston's techniques."

Table 4. Analysis of Tree Ring Data Based on Houston's Techniques.

Tree Unit	Year Estab.	Unit Age	No. of Scars / Unit	Period Between Fires	No. of Periods	Unit Age / No. of Scars	Unit Age-60 yrs. / No. of Scars
2(1)	1617	358	8	12,29,20,68, 14,25,11.	7	44.75	37.25
3(4)	1634	341	4	8,30,141.	3	85.25	70.25
5	1763	212	1	104.	1	212.00	152.00
7(6)	1523	452	3	63,59.	2	150.67	130.67
8	1615	360	7	22,48,60,20, 39,8.	6	51.43	42.86
11(10)	1740	235	8	13,44,9,11, 26,17,20.	7	29.38	21.88
12	1758	217	5	19,38,20,30.	4	43.40	31.40
13	1750	225	1	120.	1	225.00	165.00
14	1658	317	2	4.	1	158.50	128.50
15	1734	241	2	32.	1	120.50	90.50
16	1783	192	2	29.	1	96.00	66.00
18	1621	354	2	11.	1	177.00	147.00
Total		3504	45	1224	35	1393.88	1083.31
No.		12	12	35		12	12
Ave.		292	3.75	34.97		116.16	90.28

IV. PRESCRIBED FIRE

Use of Prescribed Fire for Achieving Land Management Objectives

An understanding of the nature and structure of past and present ponderosa pine (*Pinus ponderosa*) ecosystems is essential for reliable management of present ecosystems. Research findings (Biswell, 1974; Cooper, 1960; Moir, 1966; Weaver, 1951, 1959, 1961, 1967a, 1967b) provides evidence that some of the ponderosa pine ecosystems existing today bare little resemblance to those ecosystems occurring before the advent of settlement by civilized populations. Necessary fire prevention and suppression policies in the early 1900's restricted the historic role of fire in ecosystems.

Rowdabaugh (1978) provides evidence that fire plays a secondary role in ponderosa pine ecosystems along the northern Colorado Front Range. Other factors, such as climate, soils, and the vegetation complex on xeric sites are more significant to the perpetuation of these ecosystems.

Fire has long been used as a management tool for achievement of various objectives such as: (1) fuel hazard reduction, (2) control of undesirable understory species, (3) grazing enhancement, (4) wildlife habitat improvement, (5) seedbed and planting site preparation, (6) thinning dense stands of saplings (7) and, forest insect and disease control.

Land managers and the public need to understand that the role of fire as a *process* in ecosystem development provides the basic foundation for establishing guidelines in using fire as a management tool (Mutch, 1976).

Fire history studies and prescribed fires provided the basic foundation for defining the role of fire in ponderosa pine ecosystems of Northern Colorado. The Eagles Cliff and Mill Creek prescribed fires purveyed research sites for short and long-term fire effects (vegetation, fuels, and soils) studies of ponderosa pine ecosystems. Research findings from the prescribed fires will provide input into the development of a fire management plan for those ecosystems.

The Eagles Cliff Prescribed Fire

(1) Specific Objectives

The specific objectives of this fire are as follows:

(1) Provide a research site for evaluating short and long-term fire effects studies.

(2) Reduce hazardous fuel accumulations resulting from mountain pine beetle control activities.

(3) Social-political factors; i.e., demonstrate to the public the use of fire as a management tool.

(4) Provide training in the implementation and evaluation of prescribed fire to U.S. Forest Service and National Park Service personnel in the Rocky Mountain Region.

(2) General Site Description

(a) Locale

The Eagles Cliff site, approximately 35 acres, is located in Rocky Mountain National Park at an elevation of 8900 feet. The selection of this site was based upon its characteristics being representative of ponderosa pine ecosystems and fire history of the area. The soil is a shallow sandy loam with the parent material being a Pikes Peak granite. Large rock outcroppings are scattered throughout the area. The site has a south aspect and a slope of 10 to 50 percent with the average being 32 percent.

(3) Site Treatment for Mountain Pine Beetle Control

Ponderosa pine ecosystems along the Colorado Front Range have been plagued by the mountain pine beetle (Dendroctonus ponderosae Hopk.) for the past five years. A large-scale beetle control program has been launched in an effort to retard the beetle outbreak. A beetle control operation was conducted on the research site several months prior to burning. The activities of this operation consisted of felling and lopping the beetle infested trees on the site. Several one-half acre areas of hazardous fuel accumulations (i.e., slash fuel loadings greater than forty tons per acre) scattered over the site resulted from beetle control activities. Ignition in these slash fuels under severe fire weather conditions (i.e., defined as one and ten-hour timelag fuel moistures less than six and ten percent, respectively; wind velocity greater than ten miles per hour and relative humidity less than twenty percent) could generate enough heat to cause torching of the overstory. Firebrands resulting from torching could be transported by the wind to generate spot fires in adjacent areas. Large fuel concentrations resulting from beetle control activities provided an additional dimension in developing the burning prescription and plans.

(4) Fuel Loadings

Information pertaining to the ground and surface fuel complex were collected during August 1975. Two sampling techniques were employed to provide fuels data for estimating fuel loadings of the research site.

The planar intersect technique (Brown, 1974a) was used for data collection of downed woody material. Use of the relative-estimate technique (Hutchings and Schmautz, 1969; Brown, 1974b) provided fuels data of herbaceous vegetation (live and dead), litter, and duff. Prior to burning, the herbaceous vegetation loads (live and dead) were adjusted to account for the seasonal change of the vegetation condition.

Pre-fire fuel loadings by ground and surface fuel components are presented in Table 5. Statistics by fuel type and fuel components are presented in Table 6.

(5) Burning Prescription

The burning prescription and ranges of prescription parameters are outlined in Table 7. Achievement of management objectives (i.e., specific burning objectives and desired fire behavior), social, political, and environmental factors and safety were the criteria used in the development and selection of the burning prescription.

Prescription parameters and their associated ranges were selected on the basis of yielding the desired fire behavior for achievement of burning objectives. Table 8 presents hourly fuel moistures and weather data recorded during the Eagles Cliff prescribed burn (October 3-4, 1975). Surface fuel components moisture contents were sampled on-site during buring operations. Fuel moisture samples were weighed prior to and following oven-drying at 105° C for 24 hours to determine their respective moisture contents. Fuel moistures are expressed as a percent of oven-dry weight. Weather variables; air temperature, relative humidity, and wind velocity, were measured using a portable weather station and belt-weather kits.

(6) Post-Fire Analysis

Post-fire and second-year post-fire evaluations were performed on the Eagles Cliff prescribed fire site. The analysis included changes in the fuel and vegetation complex, soil nutrient levels, fire behavior, and achievement of burning objectives.

(a) Fuel Loadings

Post-fire ground and surface fuel components were sampled using the techniques described earlier under "Fuel Loadings." Sampling techniques were employed on the same plots used for pre-fire fuel sampling such that a direct comparison of fire effects on fuels, vegetation, and soils would be obtained.

The post-fire fuel inventory was completed two weeks after burning. The degree of fuel consumption by ground and surface fuel components were derived from this inventory and the total evergy released for each plot was calculated. Post-fire fuel loadings by ground and surface fuel components are presented in Table 9.

The degree of fuel consumption by ground and surface fuel components are presented in Table 10. This information was derived from a direct comparison of pre-fire fuel data, Table 5, and post-fire fuel data, Table 9. The average degree of fuel consumption for the slash fuel plots (plot numbers 11, 12, 19, and 30) is 70.3 percent and 69.2 percent for the non-slash fuel plots.

Referring to the slash fuel plots, the average degree of fuel consumption is 100.0 percent for the 0.0-0.24 inch, 0.25-0.99 inch, and 1.0-2.99 inch downed woody size classes. However, the degree of fuel consumption for the greater than 3.0 inch downed woody size class is approximately 43.7 percent. This is the result of 80 percent of the 3.0 plus inch material being greater than 5.0 inches in diameter, thereby, reducing the burning efficiency of that fuel bed. Litter, duff, and herbaceous vegetation (both live and dead) fuels were 100.0 percent consumed.

Non-slash fuel plots did not experience "total" fuel consumption. The average degree of fuel consumption for the 0.0-0.24, 0.25-0.99, 1.0-2.99 and greater than 3.0 inch downed woody material are 75.8, 89.8, 100.0, and 100.0 percent, respectively. The consumption of litter and duff were 88.1 and 60.9 percent, respectively. The herbaceous vegetation, both live and dead grasses and forbs, were 96.0 percent consumed as a result of the fire.

Another fuels inventory was conducted on the same plots eighteen months after the post-fire fuels inventory. The sampling techniques used were the same as the two previous inventories. Table 11 displays the second-year post-fire fuel loadings by ground and surface fuel components.

A comparison of pre-fire fuel conditions (Table 5) and second-year post-fire fuel conditions (Table 11) provides a means of deriving the percentage of initial pre-fire fuel conditions present eighteen months after burning. In regard to the slash fuel plots, herbaceous vegetation increased approximately 5.1 percent of the initial pre-fire condition. This vegetative response resulted from a "recycling" effect of nutrients into the soil and plant responses to high levels of heat energy (refer to Table 12 heat values). On non-slash plots, however, the herbaceous vegetation loading was only 73.5 percent of the initial pre-fire fuel condition.

(b) Fire Behavior

Fire behavior measurements were conducted on fourteen plots from which fuel, soils, and vegetation data were inventoried prior to burning. Fire behavior descriptors measured were linear rate of spread (feet per minute), flame length (feet from mid-flame zone), total heat released (BTU per square foot), and Byram's fireline intensity (BTU per fireline foot second). Table 12 presents a summary of fuel loadings and fire behavior characteristics for the Eagles Cliff prescribed burn.

Slash fuel plots, as a result of heavy fuel loadings, exhibited the larger numerical values for rate of spread, flame length, fireline intensity, and total heat released. Flame length measurements recorded during the fire were checked with estimations made from time-lapsed photography. Using flame length data, Byram's fireline intensity was calculated using the predicitive equation (Byram, et. al., 1966):

$$L \approx 0.45[I]^{0.46}$$

where

L = flame length, feet.

I = Byram's fireline intensity, BTU/foot second.

Total heat released was calculated using the weighted average fuel consumption value for each fuel bed component multiplied by its respective heat content value and summing the products for the plot. Refer to Appendix A for the specific heat content values by fuel bed component used in calculating total heat released.

Knowing Byram's fireline intensity, the lethal scorch height for coniferous crowns can be calculated using Van Wagner's equation (Van Wagner, 1973):

$$h_s \approx 3.94\ I^{1.16}[(0.107\ I + U^3)^{.5}(60-T)]$$

where

h_s = lethal scorch height, meters.

I = Byram's fireline intensity, BTU/foot second.

U = wind velocity, meters/second

T = ambient air temperature, degrees centigrade.

The equation is based on a scorch temperature of 60° C or 140° F. The lethal scorch height for any ambient temperature can be determined using the scaling relationship (Albini, 1976):

$$h_s[T] = [63.0/(140.0-T)]\ h_s\ (77°\ F)$$

The Mill Creek Prescribed Fire

(1) Specific Objectives

The specific objectives of this prescribed fire are as follows:

(1) Establish a research site for evaluating short and long-term fire effects studies (primarily herbaceous vegetation, shrubs, and fuels) in ponderosa pine ecosystems.

(2) Social-political factors; i.e., use of fire as a natural resource management tool.

(3) Provide training in the implementation and evaluation of prescribed burning to U.S. Forest Service and National Park Service personnel in the Rocky Mountain Region.

(2) General Site Description

(a) Locale

The Mill Creek site, 2 acres, is located in Rocky Mountain National Park at an elevation of 8400 feet. Cover type was of a decandent ponderosa pine overstory and an understory dominated by bunchgrasses, big sagebrush (*Artemisia tridentata*), and bitterbrush (*Purshia tridentata*). The ponderosa pine overstory was infested by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.). However, beetle control activities were not undertaken on this site.

A shallow sandy loam characterizes the soil type. The soil parent material is a Pikes Peak granite. Large rock outcroppings are located on areas adjacent to the site, however, the site itself is virtually free of rock outcroppings.

Terrain slopes range from 3 percent at the lower end (south side) to 32 percent near the upper section (north side). The site has a south-southeast aspect.

(2) Fuel Loadings

Information concerning the ground and surface fuel complex were collected during the 1976 summer-fall (August and September) field season. Downed woody material, litter and duff, herbaceous vegetation, and woody shrubs constituted the fuels inventory. Two sampling techniques were implemented for obtaining fuels data necessary to estimate fuel loadings of the research site.

A modified version of the planar intersect technique (Brown, 1974) provided a means for data collection of downed woody material. Shrub biomass data were sampled using methods described by Hutchings and Schmautz (1969), and Brown (1974 and 1976). Total aboveground and leaf biomass estimations were derived using linear regression equations (Brown, 1976) in which basal stem diameters represented the independent variable.

Fuels data of herbaceous vegetation (live and dead), litter, and duff were sampled using the relative-estimate technique (Hutchings and Schmautz, 1969; Brown, 1974). Fuels data of herbaceous vegetation were sampled two weeks prior to burning, thereby reflecting the seasonal change in the herbaceous vegetation condition (i.e., percent cured).

Pre-fire fuel loadings by ground and surface fuel components are presented in Table 13. Fuel loadings contributed by shrub components are included in the "Total Fuel Loading" category in Table 13.

Presented in Table 14 are pre-fire fuel loadings contributed by dead and live shrub components. For each plot, the dominate species (common name) contributing to the fuel loading are listed in this table. Fuel loadings contributed by shrubs were delineated into several components: (1) total leaf weight, (2) branchwood weight by individual size classes (0.0-0.51 cm, 0.51-2.00 cm, and 2.01 cm or larger), and (3) total aboveground weight. These components were selected on the basis of the analytical method used to estimate shrub biomass. An assumption was made in that dead shrub

leaf material would contribute to the ground litter loading rather than remaining on the shrub. Therefore, the total leaf weight within the dead category was zero.

(3) Burning Prescription

Achievement of management and research objectives, social-political and environmental factors, and safety were the criteria used in the formulation of the burning prescription. The burning prescription and ranges of prescription parameters are presented in Table 15.

Hourly fuel moistures and weather data recorded during the Mill Creek prescribed burn (October 14, 1976) are presented in Table 16. Weather variables; air temperature, relative humidity, and wind velocity were measured using belt-weather kits. Surface fuels moisture contents were sampled onsite during burning operations. Fuel moisture samples were weighed prior to and following oven-drying at 105° C for 24 hours to determine their respective moisture contents. Fuel moistures are expressed as a percent of oven-dry weight.

(4) Post-Fire Analysis

Post-fire and first-year post-fire evaluations were conducted on the Mill Creek prescribed fire site. Included in the analysis were changes in the fuel and vegetation complex, and fire behavior.

The post-fire fuel inventory was completed immediately following burning operations. Ground and surface fuel components were sampled using the techniques described earlier under the "Fuel Loadings" section on page Sampling techniques were employed on the same plots used for pre-fire fuel sampling such that a direct comparison of fire effects on fuels and vegetation would be obtained. The degree of fuel consumption by ground and surface fuel components were derived from this inventory and the total energy released for each plot was calculated. Post-fire fuel loadings by ground and surface fuel components are presented in Table 13.

The degree of fuel consumption by ground and surface fuel components of downed woody material and herbaceous vegetation are presented in Table 17. This information was derived from a direct comparison of pre- and post-fire fuels data listed in Table 13. When viewing the burn area as a whole (includes all fuel components), the average degree of fuel consumption is 49.3 percent. Approximately 83.3 percent of the litter and both live and dead herbaceous vegetation were consumed. Of the downed woody material, the

0.25 to 0.99 inch size class had the largest degree of consumption; 54.4 percent. This result is best explained by the fact that the 0.25 to 0.99 inch size class represented 50.3 percent of the woody material available for combustion and that this size class was present in areas where the fuel bed was dominated by grasses and shrubs.

Table 18 displays the degree of fuel consumption for the various shrub components. This information resulted from a direct comparison of pre-fire shrub loadings, Table 14, and post-fire shrub loadings, Table 19. The average degree of fuel consumption for live portions of shrubs is 65.3 percent. The 0.0 to 0.51 cm branchwood size class had the highest degree of fuel consumption, 62.6 percent, among live portions of shrubs. A comparison of dead shrub materials was not conducted because of the subjectivity involved with determining what fraction of the pre-fire dead shrub materials was consumed.

A fuels inventory was conducted on the same plots one year after the initial post-fire fuels inventory. Sampling techniques employed were the same as the two previous inventories conducted on Mill Creek site. Table 19 displays the first-year post-fire fuel loadings by ground and surface fuel components. First-year post-fire shrub loadings showed no change from the initial post-fire shrub data presented in Table 19.

Percentages of initial pre-fire fuel conditions present one year following burning were derived from a direct comparison of pre-fire fuel conditions (Tables 13 and 14) and first-year post-fire fuel conditions (Tables 13 and 19). Herbaceous vegetation increased approximately 3.1 percent of the initial pre-fire condition. Downed woody material increased 1.6 percent of the initial pre-fire condition. The 0.25 to 0.99 inch size class showed the most notable increase. There are two possible explanations for this increase. One, is that crown scorching of the overstory weakened the branching structure such that woody material from the overstory fell, thus contributing to the surface fuels. Secondly, that shrub mortality contributed woody material to the surface fuel complex. Litter loadings were approximately 64.4 percent of the initial pre-fire condition. Certain plots showed an increase over the initial pre-fire litter loading as a result of crown scorching increasing needle cost accumulations.

Fire behavior measurements were conducted on all six plots from which fuel and vegetation data were sampled prior to burning. Fire behavior descriptors measured were linear rate of spread (feet per minute), flame length (feet from mid-flame zone), total heat released (BTU per square foot), and Byram's fireline intensity (BTU per fireline foot second). Table 20 presents a summary of fuel loadings and fire behavior characteristics for the Mill Creek burn.

Fire spread in shrubs was dependent on the litter and herbaceous vegetation loading underneath the shrubs. If the litter and herbaceous vegetation loading was light and discontinuous, the result was a lack of heat required to create ignition of the shrubs. Fire spread was often discontinuous without a driving wind to serve as the propagating flux.

Methods of calculating the various fire behavior descriptors are the same as those described for the Eagles Cliff burn under the section titled, "Fire Behavior."

Table 5. Prefire fuel loading by ground and surface fuel components of the Eagles Cliff prescribed fire site.

	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" rotten	litter	duff	live	dead	Loading
3	.2596	1.3145	---	---	---	.5286	4.4467	.0022	.1070	6.6586
11*	.2144	10.7598	11.9315	37.1404	---	1.2721	6.2253	.0050	.2414	67.7897
12*	.0614	1.9625	1.7099	15.7023	---	1.9924	4.4467	.0011	.0535	25.9298
14	.0705	---	---	---	---	.4419	3.1127	.0072	.3513	3.9836
16	.0467	---	---	---	---	.6809	18.2313	.0096	.4697	19.4382
19*	.2731	6.7855	6.7567	47.0254	1.3112	2.5950	8.0040	.0013	.0649	72.8171
20	.0461	.1604	---	---	---	.6397	12.0060	.0052	.2564	13.1138
21	.0230	.4795	---	---	---	.0636	.4447	.0207	1.0135	2.0450
22	---	.1589	---	---	---	.2674	3.5573	.0203	.9950	4.9989
26	.1365	---	---	---	---	1.3075	16.4527	.0068	.3325	18.2360
27	.2729	.3168	---	---	---	.6551	13.7847	.0176	.8623	15.9094
28	.0454	---	---	---	---	.6831	4.8913	.0041	.2009	5.8248
29	.0223	1.3986	---	---	---	1.3870	21.7887	.0048	.2364	24.8378
30*	.3026	13.5324	4.2109	27.4719	---	.7534	24.9014	.0075	.0360	71.2161
32	.1159	.4843	---	---	---	.9032	4.0020	.0052	.2544	5.7650
33	.1623	.6457	---	---	---	.9032	7.5593	.0052	.2544	9.5301
34	.0921	.6415	1.1678	---	---	1.0332	32.9053	.0011	.0542	35.8952
35	.0467	---	---	1.2339	---	2.3317	15.1187	.0034	.1680	18.9024
40	.1790	.3116	---	---	---	1.6989	23.1227	.0009	.0458	25.3589
41	.1990	.1540	1.1214	16.1275	---	1.2562	13.7847	.0002	.0102	32.6532
42	.0217	---	---	---	---	.2213	7.1147	.0026	.1240	7.4843
43	.0223	.1620	---	---	---	.3292	2.6680	.0041	.2002	3.3858
44	---	.3286	---	---	---	.9083	3.1127	.0036	.1748	4.5280

* denotes slash fuels

Table 6. Pre-fire loading statistics of the Eagles Cliff prescribed fire site.

Statistics		Downed Woody Size Classes: 0.0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	Forest Floor: litter	duff	Herbaceous Vegetation: live	dead	Total Fuel Loading
		Loading by Ground and Surface Fuel Component (Tons/Acre)									
Slash plots:											
	$\bar{x}$	.2129	8.2601	6.1523	31.8350	.3278	1.6532	10.8944	.0037	.0990	47.8436
	s	.1074	5.0292	4.3691	13.3940	.6556	.8077	9.4503	.0031	.0957	26.0192
	CV	50.47	60.89	71.02	42.07	200.00	48.85	86.74	82.96	96.72	54.38
	$s_{\bar{x}}$	.0537	2.5146	2.1846	6.6970	.3278	.4038	4.7251	.0015	.0479	13.0096
Range	Max.	.3026	13.5324	11.9315	47.0254	1.3112	2.5950	24.9014	.0075	.2414	72.8171
	Min.	.0614	1.9625	1.7099	15.7023	---	.7534	4.4467	.0013	.0360	25.9298
	PE	25.23	30.44	35.51	21.04	100.00	24.43	43.37	41.48	48.36	27.19
Non-slash plots:											
	$\bar{x}$	.0927	.3451	.1205	.9138	---	.8547	10.9529	.0066	.3216	13.6078
	s	.858	.4164	.3610	3.6950	---	.5604	8.7416	.0062	.3048	10.3401
	CV	92.52	120.67	299.60	404.37	---	65.57	79.81	94.72	94.76	75.99
	$s_{\bar{x}}$	.0197	.0955	.0828	.8477	---	.1286	2.0055	.0014	.0699	2.3722
Range	Max.	.2729	1.3986	1.1678	16.1275	---	2.3317	32.9053	.0207	1.0135	35.8952
	Min.	---	---	---	---	---	.0636	.4447	.0002	.0102	2.0450
	PE	21.22	27.68	68.73	92.77	---	15.04	18.31	21.73	21.74	17.43

where: Sample mean: $\bar{x} = \frac{\Sigma x}{n}$

Standard deviation: $s = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}}$

Coefficient of variation: $CV = \frac{s}{\bar{x}} (100\%)$

Standard error of the mean: $s_{\bar{x}} = \frac{s}{\sqrt{n}}$

Range of maximum and minimum values obtained

Sampling error: $PE = \frac{s_{\bar{x}}}{\bar{x}}$

Table 7. Burning Prescription for the Eagles Cliff Prescribed Fire.

Burning Prescription Parameters	Prescription Contents	
Fuel Type:	Decandent ponderosa pine overstory with heterogenous understory of bunchgrass, species and bitterbrush. Several one acre areas of homogenous slash fuels. Ground fuel component primary pine needle litter.	
Time of Year:	Between September 7 and November 15, 1975 when grasses are 50 percent cured.	
Time of Day for ignition	0800 - 1400 hours.	
Fuel Moisture Ranges during burning:	Ground fuel (litter)	6-12 percent
	Herbaceous vegetation	4-10 "
	One-hour timelag fuels	4-10 "
	Ten-hour " "	6-12 "
	One-hundred hour timelag fuels	8-16 "
Air Temperature:	45° F to 80° F	
Relative Humidity:	8 to 22 percent	
Wind Velocity:	5 to 12 miles per hour (20 foot windspeeds)	
Wind Direction:	west-northwest	
State of Weather:	Clear to partly cloudy with no major frontal systems approaching. Less than .25 inch of precipitation 2 days prior to burning.	
Atmospheric Stability:	Smoke dispersal critical, no temperature inversion present.	

Table 8. Hourly fuel moistures and weather data recorded during the Eagles Cliff prescribed burn (Oct. 3-4, 1975).

Date	Time of Day	Weather Variables: Temperature °F	Weather Variables: Relative Humidity percent	Weather Variables: Wind Velocity mph	Fuel Moisture (%) by Surface Fuel Components: 0.0-0.24"	Fuel Moisture (%) by Surface Fuel Components: 0.25-0.99"	Fuel Moisture (%) by Surface Fuel Components: 1.0-2-99"	Fuel Moisture (%) by Surface Fuel Components: Herbaceous Vegetation Dead
10-3-75	0800	49	---	3-5	---	---	---	---
	0900	52	24.5	< 3	10.0	14.0	15.0	9.5
	1000	62	20.5	< 3	8.0	10.0	13.0	7.0
	1100	68	15.0	< 6	7.0	9.0	12.0	6.0
	1200	71	14.0	6-7	6.0	9.0	10.0	6.0
	1300	74	13.0	5-6	6.0	8.0	9.0	4.0
	1400	76	9.0	6-7	4.0	6.0	8.0	3.0
	1500	74	10.0	8-9	4.0	6.0	8.0	3.0
	1600	76	10.0	4-5	---	---	---	---
10-4-75	0800	52	---	8-10	---	---	---	---
	0900	56	---	8-9	---	---	---	---
	1000	60	---	8-10	7.0	9.0	12.0	6.0
	1100	62	---	8-9	7.0	9.0	12.0	6.0
	1200	68	13.5	8-9	6.0	7.0	10.0	5.0
	1300	71	12.4	9-10	5.0	6.0	9.0	5.0
	1400	72	---	9-10	4.0	6.0	8.0	3.0
	1500	---	---	---	---	---	---	---
	1600	---	---	---	---	---	---	---

Table 9. Post-fire fuel loading by ground and surface fuel components of the Eagles Cliff prescribed fire site.

	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	duff	live	dead	Loading
3	.0236	---	---	---	---	---	2.2233	---	---	2.2463
11*	---	---	---	22.2807	---	---	---	---	---	22.2807
12*	---	---	---	5.0926	---	---	---	---	---	5.0926
14	.0235	---	---	---	---	.0674	.8893	.0001	.0016	.9819
16	---	---	---	---	---	---	---	---	---	---
19*	---	---	---	32.1946	---	---	---	---	---	32.1946
20	.0230	---	---	---	---	---	---	---	---	.0230
21	.0230	---	---	---	---	---	.8893	---	---	.9123
22	.0228	---	---	---	---	---	1.7787	---	---	1.8015
26	.0910	---	---	---	---	---	.8893	---	---	.9803
27	---	---	---	---	---	.0808	9.7827	---	---	9.8635
28	---	.1579	---	---	---	---	.4447	---	---	.6026
29	---	---	1.1316	---	---	---	16.0080	---	---	17.1396
30*	---	---	---	17.7148	---	---	---	---	---	17.7148
32	---	.1614	---	---	---	.1282	.8893	.0007	.0362	1.2949
33	---	.3229	---	---	---	.1042	.8893	.0004	.0197	1.3365
34	---	---	---	---	---	.1265	.8893	.0001	.0020	1.0179
35	---	---	---	---	---	1.1717	2.2233	.0007	.0332	3.4289
40	---	---	---	---	---	---	10.2273	---	---	10.2273
41	---	---	---	---	---	.4406	7.3370	---	---	7.7776
42	.0217	---	---	---	---	.1649	6.2253	.0008	.0368	6.4495
43	---	---	---	---	---	---	1.2932	---	---	1.2932
44	.0236	.1643	---	---	---	---	2.2233	---	---	2.4112

* denotes slash fuels

Table 10. Fraction of fuel consumption by ground and surface fuel components of the Eagles Cliff prescribed fire site.

	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" rotten	litter	duff	live	dead	Loading
3	.909	1.0	---	---	---	1.0	.500	1.0	1.0	.663
11*	1.0	1.0	1.0	.400	---	1.0	1.0	1.0	1.0	.671
12*	1.0	1.0	1.0	.676	---	1.0	1.0	1.0	1.0	.830
14	.667	---	---	---	---	.848	.714	.986	.995	.754
16	1.0	---	---	---	---	1.0	1.0	1.0	1.0	1.0
19*	1.0	1.0	1.0	.315	1.0	1.0	1.0	1.0	1.0	.558
20	.500	1.0	---	---	---	1.0	1.0	1.0	1.0	.998
21	0.0	1.0	---	---	---	1.0	0.0	1.0	1.0	.554
22	0.0	1.0	---	---	---	1.0	.500	1.0	1.0	.640
26	.333	---	---	---	---	1.0	.946	1.0	1.0	.946
27	1.0	1.0	---	---	---	.877	.290	1.0	1.0	.380
28	1.0	---	---	---	---	1.0	.909	1.0	1.0	.897
29	1.0	1.0	---	---	---	1.0	.265	1.0	1.0	.310
30*	1.0	1.0	1.0	.355	---	1.0	1.0	1.0	1.0	.751
32	1.0	.667	---	---	---	.858	.778	.865	.858	.775
33	1.0	.500	---	---	---	.885	.882	.923	.923	.860
34	1.0	1.0	1.0	---	---	.878	.973	.909	.963	.972
35	1.0	---	---	1.0	---	.496	.853	.794	.802	.819
40	1.0	1.0	---	---	---	1.0	.558	1.0	1.0	.597
41	1.0	1.0	1.0	1.0	---	.649	.468	1.0	1.0	.762
42	0.0	---	---	---	---	.255	.125	.692	.703	.138
43	1.0	1.0	---	---	---	1.0	.515	1.0	1.0	.618
44	1.0	.500	---	---	---	1.0	.286	1.0	1.0	.468

* denotes slash fuel plots

Table 11. Second-year post-fire fuel loading by ground and surface fuel components of the Eagles Cliff prescribed fire site.

	Loading by Ground and Surface Fuel Components (Tons/Acre)								
						Forest Floor	Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	live	dead	Loading
3	.0648	.2506	---	---	---	.6963	.0709	.0018	1.0844
11*	---	---	.6701	30.2227	---	.6457	.6759	.0933	32.3077
12*	---	.0523	.3430	3.5027	---	.2820	.3500	.0861	4.6161
14	.0902	.3663	---	---	---	.5721	.3026	.0163	1.3475
16	.0432	.3008	---	---	---	.5383	.1966	.0106	1.0895
19	.0891	.4134	.3387	9.6063	---	1.1145	.5070	.0699	12.1389
20	.0220	.2045	---	---	---	.6394	.0616	.0033	.9308
21	.0226	.1570	---	---	---	.2244	.2859	.0331	.7230
22	.0216	.1506	---	---	---	1.3348	.3397	.0285	1.8752
26	.0874	.1521	---	---	---	.3403	.5308	.1530	1.2636
27	.0661	.3578	---	---	---	.4017	.1080	.0091	.9427
28	.1354	.1047	.3430	---	---	.2072	.2635	.0305	1.0843
29	.0220	.4601	---	---	---	.1205	.9227	.0237	1.5490
30*	.0437	.2534	---	23.5593	---	.7089	.2204	.0542	24.8399
32	---	.2008	---	---	---	.1579	.0364	.0009	.3960
33	.0216	.4015	.6580	---	---	.9836	.1463	.0079	2.2189
34	.1128	1.3084	.3430	---	---	.5876	.3309	.0383	2.7210
35	.0891	.8267	1.0160	---	---	2.0300	.2332	.0270	4.2220
40	.0437	.1521	.3322	---	---	1.9492	.0933	.0050	2.5755
41	---	.3041	---	---	---	2.3978	.0111	.0003	2.7133
42	.1748	.8110	---	---	---	2.4321	.1741	.0094	3.6014
43	.0434	.2519	---	---	---	.5842	.0549	.0046	.9390
44	.0458	.3718	---	---	---	2.5971	.0195	.0005	3.0347

* denotes slash fuels

Table 12. Fuel loadings and fire behavior descriptors of the Eagles Cliff prescribed fire (approx. 35 acres).

	FUEL LOADING		FIRE BEHAVIOR DESCRIPTORS			
Plot No.	Prefire Fuel Load (tons/acre)	Fuel Consumed (tons/acre)	Linear Rate of Spread (feet/minute)	Flame Length (feet)	Byram's Intensity (BTU/fireline foot second)	Total Heat Release (BTU/square feet)
3	6.6586	4.4123	14.2	8.5	594.8	1700.1
11*	67.7897	45.5090	11.5	25.5	6479.8	17604.5
19*	72.8171	40.6225	13.8	15.6	2226.5	15521.2
20	13.1138	13.0908	1.5	2.5	41.6	4837.0
26	18.2360	17.2557	4.9	4.5	149.2	6384.6
27	15.9094	6.0459	7.0	6.5	332.0	2267.4
28	5.8248	5.2222	16.7	12.2	1304.7	2001.7
30*	71.2161	53.5013	31.0	27.1	7396.3	20346.0
32	5.7650	4.4701	3.6	2.0	25.6	1715.5
33	9.5301	8.1936	14.7	7.2	414.6	3057.6
34	35.8952	34.8773	12.3	8.7	625.6	12912.9
35	18.9024	15.4735	8.9	4.4	142.1	5725.1
40	25.3589	15.1316	4.1	2.5	41.6	5636.7
42	7.4843	1.0348	1.5	1.0	5.7	382.0

* denotes slash fuels

Table 13. Fuel loading by ground and surface fuel components of the Mill Creek prescribed fire site.

	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	duff	live	dead	Loading[1/]
Pre-fire										
1	.3246	1.0547	1.0972	---	---	2.3170	6.2253	.0136	.0355	16.3461
2	.1080	1.0529	1.0953	---	---	.6742	1.3340	.0283	.1445	4.5156
3	.5758	1.1226	.5838	---	---	.1777	1.5563	.0872	.0889	8.8457
4	.0220	.4593	---	---	---	.7406	1.7787	.0366	.0468	9.9809
5	.2848	.3051	.5555	---	---	.4105	8.8933	.0517	.0661	11.0608
6	.1946	.9031	---	---	---	.7886	6.6700	.0573	.0950	18.6218
Post-fire										
1	.2813	.1507	---	---	---	---	---	---	---	5.1341
2	.1080	1.0529	1.0953	---	---	.6742	1.3340	.0283	.1445	5.3346
3	.3685	.4811	---	---	---	---	1.3340	---	---	6.8370
4	.1319	.4593	---	---	---	---	1.1858	---	---	6.8313
5	.1972	---	.5555	---	---	---	.5929	---	---	1.4288
6	.0649	.1505	---	---	---	---	1.6304	---	---	2.9035
1st year post-fire										
1	.1298	1.5067	---	---	.6302	.6563	3.1127	.0327	.0008	10.7713
2	.4104	2.5569	1.6429	---	---	.9011	1.7787	.1360	.0114	8.3348
3	.5067	.8018	1.7516	---	---	.4092	3.7797	.3013	.0163	12.2200
4	.2199	.9185	---	---	---	.3196	2.4457	.0371	.0010	8.9961
5	.3067	1.9833	---	---	---	.5492	2.6680	.0833	.0070	5.6807
6	.1946	1.5052	.5480	---	---	.4544	3.1127	.1217	.0256	7.0199

[1/] Shrub loading included in total loading

Table 14. Pre-fire fuel loading contributed by shrub components of the Mill Creek prescribed fire site.

Plot No.	Species	Category	Fuel Loading Contributed by Shrub Components (Tons/Acre): Total Leaf Weight	Total Branchwood Weight: 0-0.50 cm	Total Branchwood Weight: 0.51-2.00 cm	Total Branchwood Weight: 2.01 cm +	Total Aboveground Weight
1	bitterbrush	dead	---	.2635	.3242	.1650	.7527
		live	.7556	1.3293	1.7337	.7319	4.5255
2	bitterbrush	dead	---	---	---	---	---
		live	.0164	.0437	.0184	---	.0784
3	bitterbrush	dead	---	.0975	.1025	.0658	.2658
		live	.4773	1.4335	1.5299	.9469	4.3876
4	big sagebrush	dead	---	.3587	.4436	.1783	.9806
		live	.7778	1.8794	2.2490	1.0103	5.9164
5	bitterbrush	dead	---	.0446	.0387	---	.0833
		live	.0779	.1781	.1548	---	.4106
6	bitterbrush	dead	---	---	---	---	---
		live	1.1274	3.2478	3.7511	1.7870	9.9132

Table 15. Burning Prescription for the Mill Creek prescribed fire.

Burning Prescription Parameters	Prescription Contents
Fuel Type:	Decandent ponderosa pine overstory with heterogenous understory of bunchgrass species and bitterbrush. Ground fuel component primary pine needle litter and grasses.
Time of Year:	Between September 1 and November 15, 1976 when grasses are 60 percent cured.
Time of Day for Ignition:	1000 - 1400 hours.
Fuel Moisture Ranges during burning:	Ground fuel (litter) 6-12 percent Herbaceous vegetation 4-10 " One-hour timelag fuels 4-10 " Ten-hour timelag fuels 6-12 "
Air Temperature:	45° F to 75° F
Relative Humidity:	10 to 20 percent
Wind Velocity:	5 to 20 mph (20 foot windspeeds)
Wind Direction:	West-southwest
State of Weather:	Clear to partly cloudy with no major frontal systems approaching. No precipitation within 3 days prior to burning unless fuel conditions are too dry.
Atmospheric Stability:	Smoke dispersal not critical, however, temperature inversion is not permissable.

Table 16. Fuel Moisture and Weather Data Recorded During the Mill Creek Prescribed Burn (October 14, 1976).

			Weather Variables			Fuel Moisture (%) by Surface and Ground Fuel Components							
						Downed Woody				Herbaceous Vegetation		Shrubs	
Date	Time of Day	Plot No.	Temperature °F	Relative Humidity percent	Wind Velocity mph	0.0-0.24"	0.25-0.99"	1.0-2.99"	Liter	Dead	Live	Bitterbrush	Big Sagebrush
10-14-76	1200	---	60	20	2-7	6.6	7.2	---	12.5	5.4	56.5	81.2	68.1
	1215	2	61	18	2-7	---	---	---	---	---	---	---	---
	1330	1	59	21	2-12	---	---	---	---	---	---	---	---
	1345	3	60	20	2-8	---	---	---	---	---	---	---	---
	1414	6	60	20	2-10	---	---	---	---	---	---	---	---
	1454	5	63	18	2-6	---	---	---	---	---	---	---	---
	1511	4	61	20	2-7	---	---	---	---	---	---	---	---

Table 17. Fraction of Fuel Consumption by Ground and Surface Fuel Components of the Mill Creek Prescribed Fire Site.

Plot No.	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel Loading[1/]
	0.0.24"	0.25-0.99:	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	duff	live	dead	
1	.133	.857	1.0	---	---	1.0	1.0	1.0	1.0	.686
2	0.0	0.0	0.0	---	---	0.0	0.0	0.0	0.0	0.0
3	.360	.571	1.0	---	---	1.0	.143	1.0	1.0	.227
4	0.0	0.0	---	---	---	1.0	.333	1.0	1.0	.331
5	.308	1.0	0.0	---	---	1.0	.400	1.0	1.0	.871
6	.667	.833	---	---	---	1.0	.756	1.0	1.0	.844

1/ Shrub loading included in total loading.

Table 18. Fraction of Fuel Consumption by Shrub Components of the Mill Creek Prescribed Fire Site.

Plot No.	Species	Category	Fuel Loading Contributed by Shrub Components (Tons/Acre)				
			Total Leaf Weight	Total Branchwood Weight			Total Aboveground Weight
				0-0.50 cm	0.51-2.00 cm	2.01 cm +	
1	bitterbrush	dead	---	0.0	0.0	0.0	0.0
		live	.400	.392	.365	.610	.415
2	bitterbrush	dead	---	---	---	---	---
		live	1.0	1.0	1.0	1.0	1.0
3	bitterbrush	dead	---	0.0	0.0	0.0	0.0
		live	0.0	0.0	0.0	0.0	0.0
4	big sagebrush	dead	---	0.0	0.0	0.0	0.0
		live	.733	.765	.697	---	.772
5	bitterbrush	dead	---	.832	.832	---	.832
		live	.829	.832	.831	---	.832
6	bitterbrush	dead	---	---	---	---	---
		live	.858	.859	.864	1.0	.898

Table 19. Post-fire fuel loading contributed by shrub components of the Mill Creek prescribed fire site.

			Fuel Loading Contributed by Shrub Components (Tons/Acre)				
			Total Leaf	Total Branchwood Weight			Total Aboveground
Plot No.	Species	Category	Weight	0-0.50 cm	0.51-2.00 cm	2.01 cm +	Weight
1	bitterbrush	dead	---	.7541	.9829	.3173	2.0543
		live	.4535	.8086	1.1006	.2852	2.6478
2	bitterbrush	dead	---	.3342	.4147	.1487	.8974
		live	---	---	---	---	---
3	bitterbrush	dead	---	.0975	.1025	.0658	.2658
		live	.4773	1.4335	1.5299	.9469	4.3876
4	big sagebrush	dead	---	1.3807	1.5088	.8172	3.7070
		live	.2074	.4426	.6807	.0167	1.3473
5	bitterbrush	dead	---	.0075	.0065	---	.0140
		live	.0133	.0299	.0261	---	.0692
6	bitterbrush	dead	---	.0180	.0269	---	.0449
		live	.1599	.3423	.5107	---	1.0128

Table 20. Fuel loadings and fire behavior descriptors of the Mill Creek prescribed fire (approx. 2 acres).

	Fuel Loading		Fire Behavior Descriptors			
Plot No.	Prefire Fuel Load (tons/acre)	Fuel Consumed (tons/acre)	Linear Rate of Spread (feet/minute)	Flame Length (feet)	Byram's Intensity (BTU/fireline foot second)	Total Heat Release (BTU/square foot)
1	16.3461	11.2120	7.4	4.4	142.1	3014.9
2	4.5156	---	15.5	4.5	149.2	342.1
3	8.8457	2.0087	5.5	2.5	41.6	855.2
4	9.9809	3.1496	3.3	2.5	28.5	1242.3136
5	11.0608	9.6320	7.7	4.6	156.5	3567.9
6	18.6218	15.7183	7.2	4.8	171.7	5835.1

V. ECOSYSTEM RESPONSES TO FIRE

The peculiarities of long- and short-term response research techniques necessitated conducting these investigations as two separate studies. Even though the studies were distinct, many of the same inventory and analysis procedures were used in both. Soils, vegetation, and fuel components of each ecosystem were addressed in both the long- and short-term studies. Site characteristics are given in Table 21.

Results of the long-term and short-term studies were both compatible with the general thesis concerning ecosystem response to fire. That hypothesis is:

> Fire, in relation to variations in site characteristics and other environmental forces operating in these systems, does not play a profound role in shaping the fundamental characteristics of the ponderosa pine - mixed conifer ecosystems. Fire does not generally appear to bring about significant severe retrogression to the system. Fire rejuvenates these ecosystems by recycling nutrients through the systems and does favor certain pioneer rather than relic species.

Short-Term Responses

The Eagles Cliff and Mill Creek prescribed fires were the basis for evaluating the short-term fire effects. The majority of these studies were concerned with the larger Eagles Cliff burn. Pre-fire inventories were conducted in 1975 and successive post-fire inventories were completed during the 1976 and 1977 field seasons. Mill Creek pre- and post-fire inventories were also carried on during 1976 and 1977.

(1) Fuels

Short-term fire effects on the fuel complex of the two prescribed fire sites were discussed previously in section IV of this report, under prescribed fire results.

(2) Vegetation

The field procedures utilized to inventory the vegetative component of the ecosystems was a modification of the Braun-Blanquet Relative Sensitivity system (Clagg, 1975). A description of this procedure has been provided and can be seen in Figures 1 and 3. As indicated by the sampling method employed, the vegetative component was further sub-divided into three categories based upon species characteristics. Herbaceous, shrub, and tree species were considered separately.

Frequency of live trees and the percentage of snags (number of snags divided by total number of stems) were considered the most important tree parameters. Five tree species were recognized on the two prescribed fire sites. Only ponderosa pine had a pre-fire frequency greater than 10% and can be considered the only species of significance at these sites (Tables 22 a and b). Any change between pre- and post-fire frequencies of ponderosa pine is the result of random error in the sampling procedures. There was, however, a significant change in the percentage of snags occupying the Eagles Cliff site after the burn. The number of standing dead trees doubled one year after the fire and continued to show a slight increase the second year. There was only a very small amount of tree regeneration prior to the Eagles Cliff fire. No regeneration was encountered in either of the Eagle's Cliff post-fire studies. No regeneration was found at the Mill Creek site before or after the fire.

The lesser vegetation was analyzed in terms of its frequency and "relative density." To allow for mathematical manipulation of the grass field data the qualitative values initially recorded were quantified according to mean surface area occupied by each species. Alumeric values of 43, 34, 11, and 2 were assigned to the respective categories of abundant, common, occasional, and rare (based on 43 square feet per 1 mil acre). When considering these relative density values it is important to recall that, although expressed numerically, they have meaning only as to how they relate to each other and do not represent absolute or definitive values, but merely a comparative value.

Of the 10 shrub species occupying the sites of the two prescribed fires only Bitterbush (*Purshia tridentata*) was common on both (Tables 21 a and b). As expected both the frequencies and densities were dramatically reduced after the fires. The three years of records for the Eagles Cliff site indicate the frequency of bitterbush was reduced to half the first year after the burning and by half again the succeeding season. The Mill Creek studies verify these results. The Mill Creek site also provided an opportunity to access the fire effects on big sage (Artemisia tridentata). Big sage was severely impacted by the fire; its frequency reduced to just 25% of its initial value in a single season. The other eight shrub species were not shown to be significantly affected by the fires.

Thirty five species of forbs were recognized on the Eagles Cliff site and 34 species were identified at Mill Creek. No distinct fire effects were evident with the vast majority of these species. Goosefoot (*Chenopodium spp*), Sunflower (*Helianthella quinquenervis*), Spurge (*Euphorbia rotusta*) and Scorpionweed (*Phacelia spp.*) were typical of those species favored by the fires. Frequency of *Chenopodium spp*. increased from 2% to 87% after the Eagles Cliff burn. Onion (*Allium cernuum*), Cactus (*Opuntia spp.*), Knotweed (*Polygonum spp.*) and Miner Candle (*Cryptantha virgata*) exemplified those species adversely effected by fire.

Fire response of the grasses and sedges was generally inconclusive. Eighteen species at the Eagles Cliff site and 12 at the Mill Creek site were identified (Tables 21 a and b). *Agropynon griffithsi* was favored by fire on both sites, while *Muhlenbergia montana*'s importance was reduced after burning. Well established species of all types were rarely eliminated from these sites after burning. Likewise, only a few species were highly favored by the prescribed fires.

(3) Soils

Documentation of the chemical changes in the Eagles Cliff soils was accomplished through the analysis of soil samples obtained just prior to and one year following the prescribed fire. Samples taken at 4 and 20 centimeters below the surfaces enabled the extent of these changes to be defined. Table 23 displays the results for exchangeable calcium, potassium, phosphorus, nitrogen, and organic matter. Variability in nutrient concentrations

among sample locations is considered to be a reflextion of the relative solubility of the different elements, differences in soil texture, the relative abundance of organic matter prior to ignition, and variations in the fire's behavior.

Total nitrogen increased 2 1/4 times following the fire, with the greatest increase concentrated in the four centimeter zone. The percentage of organic matter and phosphorus both showed relatively uniform increases of 1 1/3 and 1 1/2 times respectively. Potassium was essentially unchanged and exchangeable calcium was only slightly increased.

Long Term Responses

The 12 ecologically based sites, defined by the locations of the fallen fire scarred trees, served as the foundation for conducting the long-term fire effects studies. The fire histories of these 12 sites were used to investigate responses both in terms of the number of years elapsed since the last fire event and the fire frequencies associated with each site. While the long-term studies are distinct from the short-term studies, they too substantiated the general thesis (concerning the relative importance of fire in these systems) expressed earlier.

(1) Fuels

The fuel inventory procedures utilized were those developed by Brown (Figure 2). Downed woody fuels were considered both by their size class (0 - 1/4", 1/4" - 1", 1" - 3",. 3" + Rotten, and 3" + Sound) and as a single entity. Fuels associated with the forest floor were identified as either litter or duff, and live and dead herbaceous vegetation was treated as another sub-component of the fuels. A "grand" total for all fuels at each site was also given attention.

As with the analysis of all the long-term studies, the data was received from two approaches (frequency and years since last fire). No trends were evident either in terms of fire frequencies nor years since the last fire (Tables 24 a and b). Downed woody fuel loadings ranged from .7 to almost 18 tons per acre and averaged just over 5 tons per acre. Total loadings averaged about 12 tons per acre, with duff representing the heaviest fuel component for all sites.

(2) Vegetation

The field inventory procedures and methods of data interpretation for the vegetation studies were essentially the same as those for the short-term studies. Tables 25 a and b display the results of this analysis, again by fire frequencies and years elapsed since the last fire.

Ponderosa pine and Douglas-fir were the only two tree species consistently encountered in these studies. Neither approach revealed any trends in the frequency nor the percentage of snags for any tree species.

Eleven species of shrubs were present on one or more of the 12 sites. Bitterbush (Purshia tridentata) was most frequently encountered, while Kinnikinnik (Arctostaphylos uva-ursi), juniper (Juniperus communis), and Squaw current (Ribes cereum) were located on about half of the sites. Again, no distinct trends were evident.

Only a few of the 36 species of forbs present on the sites appeared to be significantly influenced by the fire histories of the areas. Thermopsis divaricarpa and Solidago missouriensis are representative of those species that demonstrated either a general increase or decrease in importance as the years since the last fire progressed. The analysis based upon fire frequencies was also indicative of the relatively minor role fire plays in the long-term ecosystem structures of the ponderosa pine zone. Investigations of the grasses and sedges further substantiate this hypothesis.

(3) Soils

Chemical analysis of the soils at the 12 sites was not deemed justifiable with respect to the known requirements of such a study and anticipated results. The values of soil nutrient levels has been established to be a short-term phenomenon.

Table 21. Summary of physical site characteristics of the 12 historical fire sites

Site Number	Dominant Tree Species	Site Index	Basal area Per Acre	Aspect	Percent Slope	Position On Slope	Soil Texture "A" Horizon	Elevation
2(1)	Pinus ponderosa	65'	10	East-74°	12%	.50	Silt loam	7840'
3(4)	Pinus contorta	45'	40	North-338°	35%	.25	Loam	8480
7(6)	Pinus ponderosa	45'	130	North-346°	23%	.75	Loam	8400
8	Pinus ponderosa	50'	80	East-86°	10%	.50	Loam	8250
11(10)	Pinus ponderosa	45'	90	South-180°	17%	1.00	Sandy loam	8320
12	Pseudotsuga menziesii	50'	50	North-358°	39%	.75	Sandy loam	8310
13	Pinus ponderosa	50'	80	West-234°	50%	.50	Loam	9200
14	Pinus ponderosa	45'	30	South-212°	35%	.75	Loamy sand	8640
15	Pinus ponderosa	50'	40	South-220°	15%	.25	Silt loam	8720
16	Pinus ponderosa	45'	70	South-162°	26%	.25	Sandy loam	8800
18	Pinus ponderosa	50'	40	West-232°	35%	.25	Sandy loam	8400
Range		20 ft	120 ft^2	N.A.	40%	.75		1360 ft

TABLE 22a

"Data summary. Vegetation survey of Eagle's Cliff site during 1975, 1976, and 1977.

Eagles Cliff - Trees.

Species Name	1975 (-0) Frequency	1975 (-0) % snag	1976 (+1) Frequency	1976 (+1) % snag	1977 (+2) Frequency	1977 (+2) % snag
Acer glabrum	.02	0	0	---	.03	0
Juniperus scopolorum	.07	0	0	---	.01	0
Pinus ponderosa	.41	25	.53	55	.55	58
Populus tremuloides	.02	0	0	---	0	---

Regeneration was encountered only in 1975

Species Name	Number of Plots with Regeneration	Total No. of Plots	Frequency
Pinus ponderosa	3	42	.07
Populus tremuloides	2	42	.05

Eagles Cliff - Shrubs.

Species Name	1975 (-0) Frequency	1975 (-0) % snag	1976 (1+) Frequency	1976 (1+) % snag	1977 (2+) Frequency	1977 (2+) % snag
Artemisia tidentata	.02	.05	0	---	0	---
Ceanothus velutinus	0	---	0	---	.01	.03
Jamesia americana	.09	.41	.05	.09	0	---
Ceanothus velutinus	0	---	.02	.03	.01	.03
Purshia tidentata	.55	12.83	.27	2.59	.14	1.24
Ribes cereum	.21	.64	.11	.50	.32	.78
Rubus deliciosus	.19	.38	.20	.55	0	---

Eagles Cliff - Forbs.

Species Name	1975 (-0) Frequency	1975 (-0) Sensity	1976 (1+) Frequency	1976 (1+) Sensity	1977 (2+) Frequency	1977 (2+) Sensity
Achillea lanulosa	.02	.05	.02	.17	.01	.16
Allium cernuum	.07	.14	0	---	0	---
Antennaria parvifolia	0	---	.02	.03	0	---
Arabis drummondi	0	---	0	---	.06	.11
Artemisia frigida	.29	2.41	.47	1.92	.52	2.61
Artemisia ludoviciana	.43	5.62	.73	6.33	.69	7.10
Aster spp.	.05	.10	.02	.03	0	---
Astragalus flexuosus	.02	.05	.13	.67	.21	.93
Brickellia grandiflora	0	---	-	---	.03	.06
Chenopodium spp.	.02	.05	.86	12.52	.87	13.69
Chrysopsis villosa	0	---	.06	.91	.16	.69
Cryptantha virgata	.02	.05	.02	.03	.01	.03
Eriogonum umbellatum	.21	2.26	.19	.66	.17	.59
Erysimum asperum	0	---	0	---	.14	1.17
Euphorbia robusta	0	---	0	---	.06	.24
Geranium fremontii	.14	.71	.11	.22	.14	.54
Helianthella quinquenervis	0	---	.27	2.30	.31	2.01
Helianthus pumilus	.31	3.0	0	---	-	---
Lappula redowskii	0	---	.03	.20	.03	.06
Liatris punctata	0	---	0	---	.01	.03
Lithospermum spp.	0	---	0	---	.01	.03
Oneothera coronopifolia	0	---	0	---	.01	.16
Opuntia spp.	.29	3.17	.05	.09	.06	.11
Penstemon procerus	0	---	.33	1.64	.42	2.24
Phacelia spp.	0	---	.56	3.52	.46	3.08
Polygonum spp.	.05	.10	.13	.39	0	---
Potentilla fissa	.33	4.45	.58	4.11	.45	3.56
Ranunculus spp.	.05	.10	0	---	0	---
Salsola kali	0	---	0	---	.01	.03
Scutellaria brittonii	0	---	.16	1.16	.20	1.79
Senecio spp.	.02	.05	.16	.73	.03	.18
Silene scouleri	0	---	.17	1.05	.11	.99
Sisymbrium altissimum	0	---	0	---	.10	.32
Solidago missouriensis	.12	.45	.39	3.31	.39	3.20
Tragopogon dubius	.02	.05	0	---	0	---

Eagles Cliff - Grasses, Sedges, Rushes.

Species Name	1975 (-0)		1976 (1+)		1977 (2+)	
	Frequency	Sensity	Frequency	Sensity	Frequency	Sensity
Agropyron griffithsi	.19	2.55	.30	2.64	.42	3.58
Andropogon scoparius	.02	.05	.13	.82	.07	.39
Bouteloua gracilis	.24	2.64	.19	1.64	.18	1.51
Bromus anomalus	.05	1.07	0	---	.01	.03
Bromus ciliatus	.02	.05	0	---	0	---
Bromus tectorum	.02	.81	.02	.03	.04	.08
Carex spp.	.71	10.98	.69	5.67	.73	6.66
Elymus spp.	.05	.86	0	---		
Festuca idahoensis	0	---	.02	.03	.06	.11
Festuca thurberi	.26	3.45	0	---	0	---
Hesperochloa kingii	0	---	.16	1.58	.15	1.07
Koeleria cristata	.07	.91	.02	.03	.03	.18
Muhlenbergia filiculmis	0	---	.03	.06	.01	.03
Muhlenbergia montana	.67	13.71	.50	5.23	.54	3.99
Sitanion hystrix	0	---	.01	.03	.03	.06
Stipa comata	.17	4.91	.17	1.47	.08	.30
Stipa lettermani	.05	.31	0	---	0	---
Stipa scribneri	0	---	.02	.03	0	---

TABLE 22b

"Data summary. Vegetation survey of Mill Creek site during 1976 and 1977."

Mill Creek - Trees.

Species	No. of Plots where species occurred	Total Number of Plots	Frequency	Total Number of Stems	Number Live	Number Dead	% Snag
1976 (-0)							
Pinus contorta	0	24	0	---	---	---	---
Pinus Ponderosa	13	24	.54	29	28	1	.03
1977 (1+)							
Pinus contorta	1	24	.04	1	1	0	0
Pinus ponderosa	13	24	.54	23	23	0	0

	1976 (-0)		1977 (1+)	
	Frequency	% snag	Frequency	% snag
Pinus contorta	0	---	.04	0
Pinus ponderosa	.54	.03	.54	0

Mill Creek - Shrubs.

Species Name	1976 (-0) Frequency	1976 (-0) Sensity	1977 (1+) Frequency	1977 (1+) Sensity
Artemisia tridentata	.54	5.04	.13	.63
Berberis repens	0	---	.04	.08
Juniperus communis	.04	.08	.08	.17
Juniperus horizontalis	.21	.42	0	---
Purshia tridentata	1.00	16.96	.54	4.29
Ribes cereum	.46	2.04	.33	.67

Mill Creek - Forbs.

Species Name	1976 (-0) Frequency	1976 (-0) Sensity	1977 (1+) Frequency	1977 (1+) Sensity
Achillea lanulosa	.29	2.08	.42	1.58
Amaranthus retroflexus	0	---	.04	.08
Androsace septentrionalis	0	---	.04	.08
Antennaria parvifolia	.13	1.00	.13	.63
Artemisia frigida	.71	5.54	.67	.92
Artemisia ludoviciana	.92	9.71	.92	9.71
Aster spp.	0	---	.13	.25
Campanula rotundifolia	0	---	.04	.46
Chenopodium spp.	.13	.25	.71	6.67
Chrysopsis villosa	.54	2.13	.38	1.88
Cryptantha virgata	.04	.08	0	---
Epilobium paniculatum	0	---	.13	.63
Erigeron spp.	0	---	.08	.54
Eriogonum umbellatum	.88	7.38	.88	6.00
Erysimum asperum	0	---	.13	1.00
Euphorbia robusta	0	---	.33	1.04
Gaillardia spp.	0	---	.04	.46
Geranium fremontii	.17	.33	.21	.42
Lappula redowskii	0	---	.08	.17
Lithospermum spp.	0	---	.04	.08
Mertensia lanceolata	0	---	.04	.46
Penstemon angustifolius	0	---	.04	.08
Penstemon procerus	.63	5.00	.67	4.33
Phacelia spp.	.58	2.29	.63	4.63
Polygonum spp.	.33	2.17	.04	.08
Potentilla fissa	.63	4.83	.75	5.63
Pulsatilla ludoyiciana	.25	1.25	.29	1.71
Scutellaria brittonii	.29	2.08	.29	3.21
Sedum stenopetalum	.21	.79	.17	.71
Senecio spp.	.38	1.88	.46	3.17
Sisymbrium altissiumum	0	---	.29	.96
Solidago missouriensis	.88	8.50	.92	7.83
Taraxacum officinale	0	---	.04	.08
Thermopsis divaricarpa	0	---	.04	.08

Mill Creek - Grasses, Sedges, Rushes.

Species Name	1976 (-0) Frequency	Sensity	1977 (1+) Frequency	Sensity
Agropyron griffithsi	.46	3.92	.58	5.29
Bromus anomalus	.13	.25	.04	.08
Bromus tectorum	.71	8.00	.54	3.33
Carex spp.	.83	6.92	.79	7.58
Festuca idahoensis	0	---	.08	.54
Festuca ovina	0	---	.04	.46
Hesperochloa kingii	.04	.08	0	---
Muhlenbergia filiculmis	.13	1.00	0	---
Muhlenbergia montana	.63	6.71	.33	4.21
Poa spp.	.13	1.00	0	---
Sitanion hystrix	.17	.71	.17	.71

TABLE 23

"Data summary. Soil analysis of Eagle's Cliff site, pre- and post-fir.

Table 23. Data Summary. Soil analysis of Eagles Cliff site pre- and post-fire.

Pre-fire Analysis							Post-fire Analysis						
				$NaHCO_3$ Extract	NH_4OAC Extract						$NaHCO_3$ Extract	NH_4OAC Extract	
Plot No.	Depth	NO_3 - N	% O.M.	ppm P	ppm K	ppm Exch. Ca	Plot No.	Depth	NO_3 - N	% O.M.	ppm P	ppm K	ppm Exch. Ca
3	4cm	5	2.6	8	153	1270	3	4cm	3	2.5	4	75	1270
3	20cm	1	1.1	3	100	780	3	20cm	3	1.5	2	85	1070
11	4cm	10	3.1	4	98	1330	11	4cm	27	3.8	6	90	1920
11	20cm	5	1.4	2	80	780	11	20cm	4	1.7	1	75	1230
16	4cm	10	3.1	3	100	1560	16	4cm	2	3.4	2	80	1500
16	20cm	7	2.1	2	80	990	16	20cm	1	1.6	2	65	1310
19	4cm	45	2.3	11	133	920	19	4cm	3	2.1	7	65	1030
19	20cm	5	1.3	2	80	640	19	20cm	2	2.9	5	65	1290
20	4cm	1	1.3	2	105	950	20	4cm	2	1.8	2	85	970
20	20cm	1	1.3	1	93	810	20	20cm	1	1.7	1	90	950
26	4cm	6	2.4	2	120	1000	26	4cm	41	7.0	16	210	2610
26	20cm	1	0.7	2	58	590	26	20cm	6	2.8	2	130	1150
28	4cm	2	2.5	5	183	1340	28	4cm	2	2.5	1	115	1220
28	20cm	1	1.5	2	148	1020	28	20cm	1	1.7	1	120	1170
29	4cm	<1	2.3	28	195	960	29	4cm	1	4.0	17	155	1070
29	20cm	1	1.4	18	133	820	29	20cm	1	2.1	14	120	930
30	4cm	15	4.3	7	125	2340	30	4cm	8	2.6	18	170	1570
30	20cm	1	0.9	5	73	710	30	20cm	10	2.3	20	140	1340
32	4cm	<1	2.4	14	120	1259	32	4cm	6	6.7	30	160	1680
32	20cm	<1	0.9	8	88	1260	32	20cm	1	1.2	17	100	770
33	4cm	1	6.0	11	220	1261	33	4cm	40	3.5	19	210	1940
33	20cm	1	1.4	4	93	1262	33	20cm	2	1.7	4	80	970
35	4cm	<1	73.4	16	160	950	35	4cm	78	5.7	53	150	3580
35	20cm	<1	1.5	5	100	830	35	20cm	6	2.3	6	90	1370
41	4cm	1	2.3	27	210	1020	41	4cm	9	3.6	30	195	1460
41	20cm	1	2.0	11	113	910	41	20cm	3	2.2	18	130	950

TABLE 24a

"Data Summary. Fuel inventory. Loadings in tons/acre size class and strata, with respect to number of years since last fire."

Table 24a. Data Summary. Fuel Inventory. Loadings in Tons/Acre Size Class and Strata, with Respect to Number of Years Since Last Fire.

Plot No.	Years From Last Fire	Downed Woody Size Classes: 0 - .24"	.25 - .99"	1.0 - 2.99"	3.0 + Rotten	3.0 + Sound	Total - Down Woody Fuels	Forest Floor: Litter	Duff	Herbaceous Dead & Alive	Grand Total
11(10)	45	0.0648	0.3008	0.3286	---	---	0.6942	1.9948	2.3708	0.0672	5.1270
12	57	1.0156	1.4537	6.2428	2.5162	---	11.2283	1.3695	8.1902	0.0031	20.7911
3(4)	75	0.5189	0.7327	1.0291	1.8243	---	4.1050	1.1328	2.8019	0.0106	8.0503
15	100	0.3241	0.4010	8.2142	---	---	8.9393	0.6115	3.4485	0.0643	13.0636
16	100	0.2593	0.3509	---	---	---	0.6102	1.0297	1.5087	0.0671	3.2157
Average 15-16	100	0.2917	0.3760	4.1071	---	---	4.7748	0.8206	2.4786	0.0657	8.1397
18	102	0.3085	1.0224	1.6754	---	---	3.0063	2.3397	6.8970	0.0217	12.2647
13	105	0.1354	2.3027	1.3721	---	---	3.8102	4.4483	5.6038	0.0548	13.9171
8	106	0.0648	0.4010	2.6285	1.1183	13.4200	17.6326	2.6790	7.3281	0.0409	27.6806
5	108	0.2204	1.0735	0.3351	---	---	1.6290	1.0608	2.3708	0.0836	5.1442
7(6)	111	0.4106	1.1028	1.9714	7.4090	---	10.8938	1.3486	3.6640	0.0017	15.9081
2(1)	120	0.1093	1.2672	0.9967	---	---	2.3732	1.6912	15.3027	0.3905	19.7576
14	129	0.0443	0.4629	1.6857	1.1475	---	3.3404	1.0242	0.8621	0.0445	5.2712
Summation - Columns Using Ave. 15-16		3.1843	10.4957	22.3725	14.0153	13.4200	63.4878	19.9095	57.8700	0.7843	142.0516

TABLE 24b

"Data summary. Fuel loading in tons/acre by size class and strata, with respect to fire frequency."

Table 24b. Data Summary. Fuel Loading in Tons/Acre by Size Class and Strata, with Respect to Fire Frequency.

Plot No.	Fire Frequency	Downed Woody Size Classes: 0 - .24"	.25 - .99"	1.0 - 2.99"	3.0 + Rotten	3.0 + Sound	Total-Downed Woody Fuels	Forest Floor: Litter	Duff	Herbaceous Dead & Alive	Grand Total
11(10)	29.4	0.0648	0.3008	0.3286	---	---	0.6942	1.9948	2.3708	0.0672	5.1270
12	43.4	1.0156	1.4537	6.2428	2.5162	---	11.2283	1.3695	8.1902	0.0031	20.7911
2(1)	44.8	0.1093	1.2672	.9967	---	---	2.3732	1.6912	15.3027	0.3905	19.7576
8	51.4	0.0648	0.4010	2.6285	1.1183	13.4200	17.6326	2.6790	7.3281	0.0409	27.6806
3(4)	85.3	0.5189	0.7327	1.0291	1.8243	---	4.1050	1.1328	2.8019	0.0106	8.0503
16	96.0	0.2593	0.3509	---	---	---	0.6102	1.0297	1.5087	0.0671	3.2157
15	120.5	0.3241	0.4010	8.2142	---	---	8.9393	0.6115	3.4485	0.0643	13.0636
7(6)	150.7	0.4106	1.1028	1.9714	7.4090	---	10.8938	1.3486	3.6640	0.0017	15.9081
14	158.5	0.0443	0.4629	1.6857	1.1475	---	3.3404	1.0242	0.8621	0.0445	5.2712
18	177.0	0.3085	1.0224	1.6754	---	---	3.0063	2.3397	6.8970	0.0217	12.2647
5	212.0	0.2204	1.0735	0.3351	---	---	1.6290	1.0608	2.3708	0.0836	5.1442
13	225.0	0.1354	2.3027	1.3721	---	---	3.8102	4.4483	5.6038	0.0548	13.9171
Summation-Columns		3.4760	10.8716	26.4796	14.0153	13.4200	68.2625	20.7301	60.3486	0.8500	150.1912

TABLE 25a

"Data summary. Vegetation survey of 12 historical sites with respect to fire frequency."

TABLE 25a

"Data summary. Vegetation survey of 12 historical sites with respect to fire frequency."

Trees.

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	225
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Pinus contorta	F	0	.50	0	0	1.00	0	0	0	0	0	0	0
latifolia	%	---	0	---	---	17%	---	---	---	---	---	---	---
Pinus	F	1.00	1.00	.50	.75	0	1.00	.75	1.00	.50	1.00	.75	.75
ponderosa	%	13%	4%	50%	0	---	0	0	18%	50%	0	0	0
Populus	F	0	.75	0	0	0	0	0	0	0	0	0	0
tremuloides	%	---	78%	---	---	---	---	---	---	---	---	---	---
Pseudotsuga	F	0	.75	0	0	.25	.25	.25	.75	.75	.25	.25	0
	%	---	0	---	---	0	0	0	9%	0	0	0	---

Shrubs

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	225
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Arctostaphylos	D	---	---	---	---	---	---	---	---	2.75	---	---	---
tridentata	F	0	0	0	0	0	0	0	0	.25	0	0	0
Jamesia	D	---	---	---	---	---	---	---	---	---	---	---	1.00
americana	F	0	0	0	0	0	0	0	0	0	0	0	.50
Juniperus	D	---	2.75	---	---	0.50	0.50	---	0.50	---	---	---	---
communis	F	0	.25	0	0	.25	.25	0	.25	0	0	0	0
Prunus	D	---	---	---	---	---	---	---	---	---	2.75	---	---
virginiana	F	0	0	0	0	0	0	0	0	0	.25	0	0
Purshia	D	6.00	8.50	---	1.50	---	11.25	---	---	11.75	11.75	---	3.25
tridentata	F	.75	.25	0	.75	0	.50	0	0	.75	.75	0	.50
Ribes	D	---	---	0.50	0.50	---	---	8.50	---	---	8.75	---	6.50
cereum	F	0	0	.25	.25	0	0	.25	0	0	1.00	0	1.00
Rosa	D	---	---	0.50	---	---	---	---	---	---	---	---	---
woodsii	F	0	0	.25	0	0	0	0	0	0	0	0	0
Rubus	D	---	---	---	---	---	---	---	---	---	---	0.50	---
deliciosus	F	0	0	0	0	0	0	0	0	0	0	.25	0
Shepherdia	D	---	---	---	---	0.50	---	---	---	---	---	---	---
canadensis	F	0	0	0	0	.25	0	0	0	0	0	0	0
Symphoricarpos	D	---	---	0.50	---	---	---	---	---	---	---	---	---
albus	F	0	0	.25	0	0	0	0	0	0	0	0	0

Forbs

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	225
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Achillea	D	---	---	2.75	---	---	14.00	3.75	---	2.75	---	---	---
lanulosa	F	0	0	.25	0	0	.75	.75	0	.25	0	0	0
Allium	D	---	---	---	---	---	---	3.25	---	---	---	---	---
cernuum	F	0	0	0	0	0	0	.50	0	0	0	0	0
Antennaria	D	3.25	0.50	5.50	5.50	0.50	5.50	---	---	3.25	---	---	---
parvifolia	F	.50	.25	.50	.50	.25	.50	0	0	.50	0	0	0
Aquilegia	D	---	---	---	---	2.75	---	---	---	---	---	---	---
chrysantha	F	0	0	0	0	.25	0	0	0	0	0	0	0
Arabis	D	---	---	---	---	---	0.50	0.50	---	---	---	---	---
drummondi	F	0	0	0	0	0	.25	.25	0	0	0	0	0
Artemisia	D	---	---	---	0.50	---	1.00	0.50	---	1.00	6.00	---	---
frigida	F	0	0	0	25	0	.50	.25	0	.50	.75	0	0
Artemisia	D	6.00	3.25	14.00	5.50	---	16.75	28.25	---	8.25	5.50	12.25	3.75
ludoviciana	F	.75	.50	.75	.50	0	1.00	1.00	0	.75	.50	1.00	.75
Aster spp.	D	---	---	---	---	---	---	---	---	---	2.75	---	---
	F	0	0	0	0	0	0	0	0	0	.25	0	0
Brickellia	D	---	---	---	---	---	---	---	---	---	0.50	---	---
grandiflora	F	0	0	0	0	0	0	0	0	0	.25	0	0

Forbs (con't)

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	255
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Campanula	D	---	---	---	---	---	---	0.50	---	---	---	---	---
parryi	F	0	0	0	0	0	0	,25	0	0	0	0	0
Campanula	D	0.50	---	0.50	---	---	---	---	---	---	---	---	---
rotundifolia	F	.25	0	.25	0	0	0	0	0	0	0	0	0
Castilleja	D	---	---	---	---	---	---	0.50	---	---	---	---	---
linariaefolia	F	0	0	0	0	0	0	.25	0	0	0	0	0
Cerastium	D	---	---	0.50	---	---	---	0.50	---	---	---	---	---
arvense	F	0	0	.25	0	0	0	.25	0	0	0	0	0
Chrysopsis	D	0.50	---	---	2.75	0.50	9.00	6.00	---	2.75	---	2.75	0.50
villosa	F	.25	0	0	.25	.25	.50	.75	0	.25	0	.25	.25
Cryptantha	D	---	---	---	---	---	---	---	---	---	---	0.50	---
virgata	F	0	0	0	0	0	0	0	0	0	0	.25	0
Delphinium	D	0.50	---	0.50	---	0.50	---	---	---	---	---	---	---
nelsoni	F	.25	0	.25	0	.25	0	0	0	0	0	0	0
Eriogonum	D	---	---	---	---	---	---	---	---	3.25	---	---	---
umbellatum	F	0	0	0	0	0	0	0	0	.50	0	0	0

Forbs (con't)

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	255
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Erysimum	D	---	---	---	0.50	---	---	---	---	---	0.50	---	---
asperum	F	0	0	0	.25	0	0	0	0	0	.25	0	0
Euphorbia	D	---	---	---	---	---	---	---	---	0.50	---	---	---
robusta	F	0	0	0	0	0	0	0	0	.25	0	0	0
Galium	D	---	---	5.50	---	---	---	2.75	---	---	---	---	---
boreale	F	0	0	.50	0	0	0	.25	0	0	0	0	0
Geranium	D	3.25	3.25	1.00	3.25	---	1.00	0.50	---	0.50	0.50	0.50	9.00
fremontii	F	.50	.50	.50	.50	0	.50	.25	0	.25	.25	.25	.50
Lappula	D	---	---	---	---	---	---	0.50	---	---	---	---	---
redowskii	F	0	0	0	0	0	0	.25	0	0	0	0	0
Lithospermum	D	---	---	---	---	---	---	0.50	---	---	---	---	---
spp.	F	0	0	0	0	0	0	.25	0	0	0	0	0
Mertensia	D	---	---	---	0.50	---	---	---	---	---	---	---	---
lanceolata	F	0	0	0	.25	0	0	0	0	0	0	0	0
Penstemon	D	3.25	---	---	1.50	---	5.50	---	---	3.75	---	---	2.75
procerus	F	.50	0	0	.75	0	.50	0	0	.75	0	0	.25
Phacelia spp.	D	1.00	---	2.75	---	---	---	---	---	0.50	---	2.75	---
	F	.50	0	.25	0	0	0	0	0	.25	0	.25	0

Forbs (con't)

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	255
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Polygonum	D	---	---	---	---	---	2.75	0.50	---	2.75	---	---	---
spp.	F	0	0	0	0	0	.25	.25	0	.25	0	0	0
Potentilla	D	---	---	---	---	---	18.00	---	0.50	2.75	5.50	---	5.50
fissa	F	0	0	0	0	0	1.00	0	.25	.25	.50	0	.50
Rumex	D	---	---	---	---	---	---	---	0.50	---	---	---	---
acetosella	F	0	0	0	0	0	0	0	.25	0	0	0	0
Scutellaria	D	---	---	0.50	---	---	---	---	---	---	---	---	---
brittonii	F	0	0	.25	0	0	0	0	0	0	0	0	0
Sedum	D	0.50	---	---	2.75	---	1.50	0.50	---	2.75	---	---	---
stenopetalum	F	.25	0	0	.25	0	.75	.25	0	.25	0	0	0
Senecio spp.	D	5.50	---	---	2.75	---	14.00	3.25	---	3.75	---	3.25	---
	F	.50	0	0	.25	0	.75	.50	0	.75	0	.50	0
Solidago	D	0.50	4.25	5.50	---	3.75	0.50	8.75	0.50	---	3.25	---	---
missouriensis	F	.25	1.00	.50	0	.75	.25	1.00	.25	0	.50	0	0
Streptopus	D	0.50	---	---	---	---	---	---	---	0.50	---	---	---
amplexifolius	F	.25	0	0	0	0	0	0	0	.25	0	0	0
Thermopsis	D	---	---	3.25	1.00	8.50	2.75	22.50	---	5.50	---	---	---
divaricarpa	F	0	0	.50	.50	.25	.25	1.00	0	.50	0	0	0

Grasses and Sedges

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	225
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Agropyron	D	---	---	---	3.25	---	0.50	5.50	---	---	---	3.25	---
griffithsi	F	0	0	0	.50	0	.25	.50	0	0	0	.50	0
Agropyron	D	---	---	5.50	---	---	---	---	---	---	---	---	---
trachycaulum	F	0	0	.50	0	0	0	0	0	0	0	0	0
Bromus	D	---	0.50	1.00	0.50	---	11.25	---	---	0.50	---	---	---
anomalus	F	0	.25	.50	.25	0	.50	0	0	.25	0	0	0
Bromus	D	---	---	2.75	---	---	---	---	---	---	---	---	---
inermis	F	0	0	.25	0	0	0	0	0	0	0	0	0
Bromus	D	---	---	---	---	---	0.50	---	---	---	---	5.50	---
tectorum	F	0	0	0	0	0	.25	0	0	0	0	.50	0
Calamagrostis	D	9.00	2.75	---	---	---	---	---	---	---	---	---	---
purpurascens	F	.50	.25	0	0	0	0	0	0	0	0	0	0
Carex spp.	D	17.50	5.50	20.25	14.00	3.25	26.00	34.00	16.75	8.25	8.25	16.75	14.00
	F	.75	.50	1.00	.75	.50	1.00	1.00	1.00	.75	.75	1.00	.75
Festuca	D	1.50	---	---	---	---	---	---	---	---	---	---	0.50
idahoensis	F	.75	0	0	0	0	0	0	0	0	0	0	.25
Hesperochloa	D	---	---	---	11.25	---	---	---	---	---	---	---	---
kingii	F	0	0	0	.50	0	0	0	0	0	0	0	0

Grasses and Sedges (con't)

Fire Frequency		29	43	45	51	85	96	121	151	159	177	212	225
Unit Number		11(10)	12	2(1)	8	3(4)	16	15	7(6)	14	18	5	13
Koeleria	D	0.50	2.75	0.50	0.50	---	0.50	---	0.50	---	---	---	3.25
cristata	F	.25	.25	.25	.25	0	.25	0	.25	0	0	0	.50
Muhlenbergia	D	---	---	---	---	---	5.50	---	---	3.25	---	---	---
filiculmis	F	0	0	0	0	0	.50	0	0	.50	0	0	0
Muhlenbergia	D	---	---	---	8.25	---	2.75	3.25	---	---	6.50	9.50	11.25
montana	F	0	0	0	.75	0	.25	.50	0	0	1.00	.75	.50
Phleum	D	---	---	0.50	---	---	---	---	---	---	---	---	---
pratense	F	0	0	.25	0	0	0	0	0	0	0	0	0
Poa spp.	D	---	---	11.25	---	---	---	6.50	0.50	---	---	---	---
	F	0	0	.50	0	0	0	1.00	.25	0	0	0	0
Sitanion	D	---	0.50	---	---	---	2.75	---	---	---	---	0.50	3.25
hystrix	F	0	.25	0	0	0	.25	0	0	0	0	.25	.50
Stipa	D	---	---	---	0.50	---	---	---	---	---	---	---	---
comata	F	0	0	0	.25	0	0	0	0	0	0	0	0

Table 25b

"Data summary. Vegetation survey of 12 historical fire sites with respect to number of years since last fire."

Trees

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Pinus contorta	F	0	.50	1.00	0	0	0	0	0	0	0	0	0	0
latifolia	%	---	0	17%	---	--	---	---	---	---	---	---	---	---
Pinus	F	1.00	1.00	0	.75	100	.88	1.00	.75	.75	.75	1.00	.50	.50
ponderosa	%	13%	4%	---	0	0	0	0	0	0	0	18%	50%	50%
Populus	F	0	.75	0	0	0	0	0	0	0	0	0	0	0
tremuloides	%	---	70%	---	---	---	---	---	---	---	---	---	---	---
Pseudotsuga	F	0	.75	.25	.25	.25	.25	.25	0	0	.25	.75	0	.75
menziesii	%	---	0	0	0	0	0	0	---	---	0	9%	---	0

Shrubs

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Arctostaphylos	D	---	2.75	---	2.75	0.50	1.63	---	---	0.50	---	---	---	---
uva-ursi	F	0	.25	0	.25	.25	.25	0	0	.25	0	0	0	0
Artemisia	D	---	---	---	---	---	---	---	---	---	---	---	---	2.75
tridentata	F	0	0	0	0	0	0	0	0	0	0	0	0	.25
Jamesia	D	---	---	---	---	---	---	---	1.00	---	---	---	---	---
americana	F	0	0	0	0	0	0	0	.50	0	0	0	0	0
Juniperus	D	---	2.75	0.50	---	0.50	.25	---	---	---	---	0.50	---	---
communis	F	0	.25	.25	0	.25	.13	0	0	0	0	.25	0	0
Prunus	D	---	---	---	---	---	---	2.75	---	---	---	---	---	---
virginiana	F	0	0	0	0	0	0	.25	0	0	0	0	0	0
Purshia	D	6.00	8.50	---	---	11.25	5.63	11.75	3.25	1.50	---	---	---	11.75
tridentata	F	.75	.25	0	0	.50	.25	.75	.50	.75	0	0	0	.75
Ribes	D	---	---	---	8.50	---	4.25	8.75	6.50	0.50	---	---	0.50	0
cereum	F	0	0	0	.25	0	.13	1.00	1.00	.25	0	0	.25	0
Rosa	D	---	---	---	---	---	---	---	---	---	---	---	0.50	---
woodsii	F	0	0	0	0	0	0	0	0	0	0	0	.25	0
Rubus	D	---	---	---	---	---	---	0.50	---	---	0.50	---	---	---
deliciosus	F	0	0	0	0	0	0	.25	0	0	.25	0	0	0

Shrubs (con't)

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Shepherdia	D	---	---	0.50	---	---	---	---	---	---	---	---	---	---
canadensis	F	0	0	.25	0	0	0	0	0	0	0	0	0	0
Symphoricarpos	D	---	---	---	---	---	---	---	---	---	---	---	0.50	---
albus	F	0	0	0	0	0	0	0	0	0	0	0	.25	0

Forbs

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Achillea	D	---	---	---	3.75	14.00	8.88	---	---	---	---	---	2.75	2.75
lanulosa	F	0	0	0	.75	.75	.75	0	0	0	0	0	.25	.25
Allium	D	---	---	---	3.25	---	1.63	---	---	---	---	---	---	---
cernuum	F	0	0	0	.50	0	.25	0	0	0	0	0	0	0
Antennaria	D	3.25	0.50	0.50	---	5.50	2.75	---	---	5.50	---	---	5.50	3.25
parvifolia	F	.50	.25	.25	0	.50	.25	0	0	.50	0	0	.50	.50
Aquilegia	D	---	---	2.75	---	---	---	---	---	---	---	---	---	---
chrysantha	F	0	0	.25	0	0	0	0	0	0	0	0	0	0
Arabis	D	---	---	---	0.50	0.50	0.50	---	---	---	---	---	---	---
drummondi	F	0	0	0	.25	.25	.25	0	0	0	0	0	0	0
Artemisia	D	---	---	---	0.50	1.00	0.75	6.00	---	0.50	---	---	---	1.00
frigida	F	0	0	0	.25	.50	.38	.75	0	.25	0	0	0	.50
Artemisia	D	6.00	3.25	---	28.25	16.75	22.50	5.50	3.75	5.50	12.25	---	14.00	8.25
ludoviciana	F	.75	.50	0	1.00	1.00	1.00	.50	.75	.50	1.00	0	.75	.75
Aster spp.	D	---	---	---	---	---	---	2.75	---	---	---	---	---	---
	F	0	0	0	0	0	0	.25	0	0	0	0	0	0

Forbs

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Campanula	D	---	---	---	0.50	---	0.25	---	---	---	---	---	---	---
parryi	F	0	0	0	.25	0	.13	0	0	0	0	0	0	0
Campanula	D	0.50	---	---	---	---	---	---	---	---	---	---	0.50	---
rotundifolia	F	.25	0	0	0	0	0	0	0	0	0	0	.35	0
Castilleja	D	---	---	---	0.50	---	0.25	---	---	---	---	---	---	---
linariaefolia	F	0	0	0	.25	0	.13	0	0	0	0	0	0	0
Cerastium	D	---	---	---	0.50	---	0.25	---	---	---	---	---	0.50	---
arvense	F	0	0	0	.25	0	.13	0	0	0	0	0	.25	0
Chenopodium	D	---	---	---	0.50	3.25	1.88	1.00	2.75	---	0.50	---	3.25	0.50
spp.	F	0	0	0	.25	.50	.38	.50	.25	0	.25	0	.50	.25
Chrysopsis	D	0.50	---	0.50	6.00	9.00	7.50	---	0.50	2.75	2.75	---	---	2.75
villosa	F	.25	0	.25	.75	.50	.63	0	.25	.25	.25	0	0	.25
Cryptantha	D	---	---	---	---	---	---	---	---	---	0.50	---	---	---
virgata	F	0	0	0	0	0	0	0	0	0	.25	0	0	0
Delphinium	D	0.50	---	0.50	---	---	---	---	---	---	---	---	0.50	---
nelsoni	F	.25	0	.25	0	0	0	0	0	0	0	0	.25	0
Eriogonum	D	---	---	---	---	---	---	---	---	---	---	---	---	3.25
umbellatum	F	0	0	0	0	0	0	0	0	0	0	0	0	.50

Forbs (con't)

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Erysimum	D	---	---	---	---	---	---	0.50	---	0.50	---	---	---	---
asperum	F	0	0	0	0	0	0	.25	0	.25	0	0	0	0
Euphorbia	D	---	---	---	---	---	---	---	---	---	---	---	---	0.50
robusta	F	0	0	0	0	0	0	0	0	0	0	0	0	.25
Galium	D	---	---	---	2.75	---	1.38	---	---	---	---	---	5.50	---
boreale	F	0	0	0	.25	0	.13	0	0	0	0	0	.50	0
Geranium	D	3.25	3.25	---	0.50	1.00	0.75	0.50	9.00	3.25	0.50	---	1.00	0.50
fremontii	F	.50	.50	0	.25	.50	.38	.25	.50	.50	.25	0	.50	.25
Lappula	D	---	---	---	0.50	---	0.25	---	---	---	---	---	---	---
redowskii	F	0	0	0	.25	0	.13	0	0	0	0	0	0	0
Lithospermum	D	---	---	---	0.50	---	0.25	---	---	---	---	---	---	---
spp.	F	0	0	0	.25	0	.13	0	0	0	0	0	0	0
Mertensia	D	---	---	---	---	---	---	---	---	0.50	---	---	---	---
lanceolata	F	0	0	0	0	0	0	0	0	.25	0	0	0	0
Penstemon	D	3.25	---	---	---	5.50	2.75	---	2.75	1.50	---	---	---	3.75
procerus	F	.50	0	0	0	.50	.25	0	.25	.75	0	0	0	.75
Phacelia spp.	D	1.00	---	---	---	---	---	---	---	---	2.75	---	2.75	0.50
	F	.50	0	0	0	0	0	0	0	0	.25	0	.25	.25

Forbs (con't).

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Polygonum	D	---	---	---	0.50	2.75	1.63	---	---	---	---	---	---	2.75
spp.	F	0	0	0	.25	.25	.25	0	0	0	0	0	0	.25
Potentilla	D	---	---	---	---	18.00	9.00	5.50	5.50	---	---	0.50	---	2.75
fissa	F	0	0	0	0	1.00	.50	.50	.50	0	0	.25	0	.25
Rumex	D	---	---	---	---	---	---	---	---	---	---	0.50	---	---
acetosella	F	0	0	0	0	0	0	0	0	0	0	.25	0	0
Scutellaria	D	---	---	---	---	---	---	---	---	---	---	---	0.50	---
brittonii	F	0	0	0	0	0	0	0	0	0	0	0	.25	0
Sedum	D	0.50	---	---	0.50	1.50	1.00	---	---	2.75	---	---	---	2.75
stenopetalum	F	.25	0	0	.25	.75	.50	0	0	.25	0	0	0	.25
Senecio spp.	D	5.50	---	---	3.25	14.00	8.63	---	---	2.75	3.25	---	---	3.75
	F	.50	0	0	.50	.75	.63	0	0	.25	.50	0	0	.75
Solidago	D	0.50	4.25	3.75	8.75	0.50	4.63	3.25	---	---	---	0.50	5.50	0
missouriensis	F	.25	1.00	.75	1.00	.25	.63	.50	0	0	0	.25	.50	0
Streptopus	D	0.50	---	---	---	---	---	---	---	---	---	---	---	0.50
amplexifolius	F	.25	0	0	0	0	0	0	0	0	0	0	0	.25
Thermopsis	D	---	---	8.50	22.50	2.75	12.63	---	---	1.00	---	---	3.25	5.50
divaricarpa	F	0	0	.25	1.00	.25	.63	0	0	.50	0	0	.50	.50

Grasses and Sedges

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Agropyron	D	---	---	---	5.50	0.50	3.00	---	---	3.25	3.25	---	---	---
griffithsi	F	0	0	0	.50	.25	.38	0	0	.50	.50	0	0	0
Agropyron	D	---	---	---	---	---	---	---	---	---	---	---	5.50	---
trachycaulum	F	0	0	0	0	0	0	0	0	0	0	0	.50	0
Bromus	D	---	0.50	---	---	11.25	5.63	---	---	0.50	---	---	1.00	0.50
anomalus	F	0	.25	0	0	.50	.25	0	0	.25	0	0	.50	.25
Bromus	D	---	---	---	---	---	---	---	---	---	---	---	2.75	---
inermis	F	0	0	0	0	0	0	0	0	0	0	0	.25	0
Bromus	D	---	---	---	---	0.50	0.25	---	---	---	5.50	---	---	---
tectorum	F	0	0	0	0	.25	.13	0	0	0	.50	0	0	0
Calamagrostis	D	9.00	2.75	---	---	---	---	---	---	---	---	---	---	---
purpurascens	F	.50	.25	0	0	0	0	0	0	0	0	0	0	0
Carex spp.	D	17.50	5.50	3.25	34.00	26.00	30.00	8.25	14.00	14.00	16.75	16.75	20.25	8.25
	F	.75	.50	.50	1.00	1.00	1.00	.75	.75	.75	1.00	1.00	1.00	.75
Festuca	D	1.50	---	---	---	---	---	---	0.50	---	---	---	---	---
idahoensis	F	.75	0	0	0	0	0	0	.25	0	0	0	0	0
Hesperochloa	D	---	---	---	---	---	---	---	---	11.25	---	---	---	---
kingii	F	0	0	0	0	0	0	0	0	.50	0	0	0	0

Grasses and Sedges (con't).

Years From Last Fire		45	57	75	100	100	100	102	105	106	108	111	120	129
Unit Number		11(10)	12	3(4)	15	16	15-16	18	13	8	5	7(6)	2(1)	14
Koeleria	D	0.50	2.75	---	---	0.50	0.25	---	3.25	0.50	---	0.50	0.50	---
cristata	F	.25	.25	0	0	.25	.13	0	.50	.25	0	.25	.25	0
Muhlenbergia	D	---	---	---	---	5.50	2.75	---	---	---	---	---	---	3.25
filiculmis	F	0	0	0	0	.50	.25	0	0	0	0	0	0	.50
Muhlenbergia	D	---	---	---	3.25	2.75	3.00	6.50	11.25	8.25	9.50	---	---	---
montana	F	0	0	0	.50	.25	.38	1.00	.50	.75	.75	0	0	0
Phleum	D	---	---	---	---	---	---	---	---	---	---	---	0.50	---
pratense	F	0	0	0	0	0	0	0	0	0	0	0	.25	0
Poa spp.	D	0	0	0	6.50	---	3.25	---	---	---	---	0.50	11.25	---
	F	0	0	0	1.00	0	.50	0	0	0	0	.25	.50	0
Sitanion	D	---	0.50	---	---	2.75	1.38	---	3.25	---	0.50	---	---	---
hystrix	F	0	.25	0	0	.25	.13	0	.50	0	.25	0	0	0
Stipa	D	---	---	---	---	---	---	---	---	0.50	---	---	---	---
comata	F	0	0	0	0	0	0	0	0	.25	0	0	0	0

VI. FIRE MANAGEMENT STRATEGY

The development of fire management strategy for ponderosa pine and mixed conifer ecosystems in the Front Range of northern Colorado is a complex matter. Involved are federal and state laws, agency policies, fire management costs and interrelated aspects of the role of fire in ecosystems and the effects of fire on society. Indeed, there are no simple answers that will permit all wildfires to perform a natural role in ecosystems without also producing some detrimental effects to society. Compromise in use of fire and strict fire control is necessary. The development of a fire management strategy is a highly professional job in the appropriate use and control of both prescribed fires and wildfires to achieve natural resource and societal requirements.

Fire Policies

In Rocky Mountain National Park and the Arapaho-Roosevelt National Forest the fire policies are established through directives issued by the National Park Service of the U.S. Department of Interior and the Forest Service of the U.S. Department of Agriculture. During recent years the fire policies of both agencies have undergone changes reflecting many factors including concern for the role of fire in ecosystems. In addition, these policies respond to many acts of Congress including enabling legislation for the national forests and parks and a variety of laws pertaining to air and water pollution, wilderness, environmental protection and management of natural resources. In the implementation of fire policies for specific areas the National Park Service and Forest Service have a long history of close cooperation and mutual assistance.

(1) National Park Service

The basic fire policies for the National Park Service are contained in the Management Policies directive issued by the Director (U.S. Dept. of Interior, 1975) and in supplemental memorandums (National Park Service, July 22, 1976 and Oct. 22, 1976). The following portions from the 1975 Management Policies directive provide guidance for development of fire management strategy in Rocky Mountain National Park:

"Management fires, including both fires of natural origin and prescribed burns, are those fires which contribute to the attainment of the management objectives of a park through execution of predetermined prescriptions defined in detail in a portion of the approved resources management plan."

"Natural fire is the prefered means to achieve the prescriptions in natural zones."

"Prescribed burning may be used as a substitute for natural fire in the prescription for natural zones where it is determined that natural fire cannot meet the objectives."

"Clearly defined limits will be established in the prescription of all management fires, beyond which limited or complete control action will be undertaken."

"All fires not classified as management fires are 'wildfires' and will be suppressed."

"Human-caused fires will be controlled to prevent damage and to eliminate unnatural impact of the park ecosystems."

(2) U.S. Forest Service

The basic fire policies for the National Forests are contained in the U.S. Forest Service Manual, Chapter 5100 (U.S. Forest Service, 1978). The following portions of the manual provide guidance for the development of fire management strategy in the Arapaho-Roosevelt National Forests:

> "The basic fire management policy on National Forests and Grasslands is to provide well planned and executed fire protection and fire use programs that are cost effective and responsive to land and resource management goals and objectives and supportive of RPA outputs." (RPA refers to the Forest and Rangeland Renewable Resources Planning Act of 1975).
>
> "Regional Foresters shall"
>
> 1. Provide a balanced fire management program which is cost effective and commensurate with threats to life and property, public safety, values, hazards, risks, and resource output targets.
> 2. Provide for prescription fire using either planned or unplanned ignitions to protect, maintain and enhance production of National Forest resources."

"For each fire management area, Forest Supervisors shall determine objectives that include: (1) the standard of fire protection and fire use necessary to insure that land management goals and objectives can be met, (2) measurable standards, such as, the maximum individual fire size, and tolerable annual and long-term allowable burned acreage, for established fire intensity levels, and (3) as appropriate, areas for treatment by prescription fire and a schedule for the required maintenance of these areas."

Development of Fire Management Strategy

Studies of ponderosa pine and mixed conifer ecosystems have shown an important role for fire. Under various conditions of ecosystem status, resource use, public safety, fire date and location, weather and danger rating - fires may be classified as either wanted or unwanted (Barrows, 1974). The fires classified as unwanted produce net disbenefits and require suppression. The wanted fires have a high potential to produce net benefits under a carefully planned and well executed system of fire management. The principal questions to be answered in the development of fire management strategy are:

(1) How to clearly identify wanted and unwanted fires.

(2) How to select conditions, times and sites for effective and safe use of wanted fires in ecosystem management.

Wanted fires may be of two types: (1) the traditional prescribed fire carefully planned, ignited and controlled by the fire management organization; (2) the traditional wildifre (unplanned ignition) that meets the same specifications required for a prescribed fire. In all situations wanted fires should be within a precisely defined fire management area and meet a specific fire prescription.

In the ponderosa pine and intermingled mixed conifer zones of both Rocky Mountain National Park and the Arapaho-Roosevelt National Forests the most prudent choice for use of fire in ecosystem management is prescribed fire (planned ignitions). Most of these zones are occupied by people or are close to population centers. They are areas of high value and use. All fires must be carefully and professionally managed. Wildfires are a definite threat to society. However, it must also be recognized that some fires resulting from unplanned ignitions can perform a beneficial role and can be managed to prevent unwanted effects.

Fire Strategy Guide

Within the framework of existing National Park Service and Forest Service policies a fire strategy guide is presented in Figure 5. This guide has been adopted from information contained in National Park Source staff directive 76-12 (U.S. National Park Service, 1976) and U.S. Forest Service Manual (5100, 1978). Definition of terms used in the guide are as follows:

Planned Ignition. The ignition of a planned prescribed fire by fire management personnel.

Unplanned Ignition. A lightning or man-caused fire in a national forest or park and an inadvertant man-caused ignition in a national forest. (Inadvertant man-caused fires in a national park are automatically classified as wildfires by National Park Service policy, U.S. Dept. of Interior, 1975).

Fire Management Area. Designated areas where approved management plans have been developed to specify actions for the use and control of all types of fires to meet common resource management objectives.

Prescription. A specified set of fuel, weather, topographic, fire danger rating, fire behavior, temporal and spatial criteria and other variables within which a fire will be managed, confined and controlled.

Prescription Fire. A fire resulting from either planned or unplanned ignition that meets all criteria of an established prescription, resource management objectives and safety requirements. (This fire meets all of the standards for a wanted fire. Term is similar to NPS designation of Management Fire).

Escaped Fire. A fire that exceeds designated prescription or initial attack capabilities.

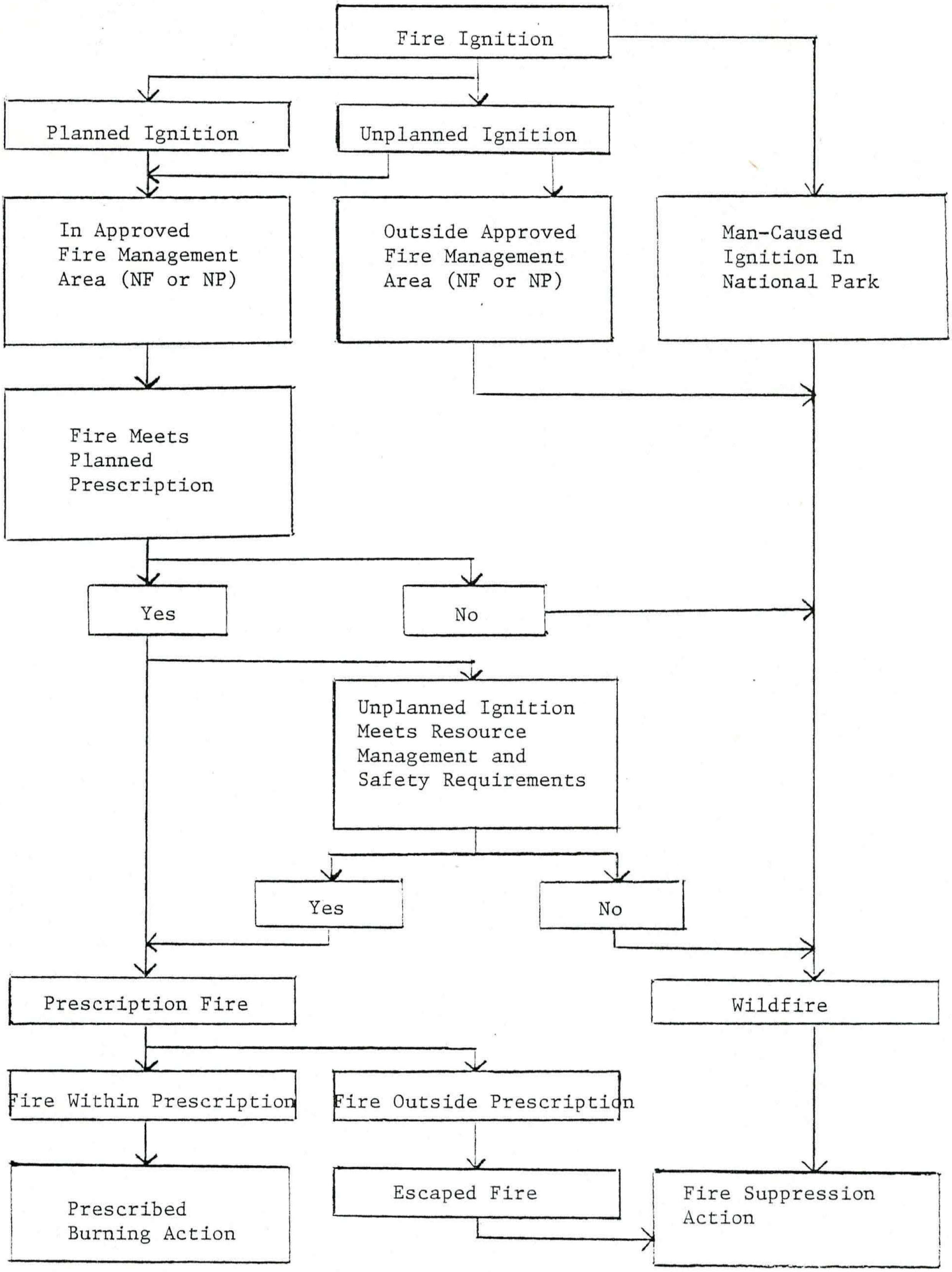
Wildfire. Any fire that is not a prescription fire. (This fire meets all of the standards for an unwanted fire).

Prescribed Burning Action. The established procedures for continuing observation, measurement, analysis, regulation, confinement and control of a prescription fire extending throughout its life from ignition to final mop-up and extinguishment.

Fire Suppression Action. The established procedures for situation analysis, control force organization and management and appropriate application of total or modified supression of a wildfire extending throughout its life from designation as a wildfire through final mop-up and extinguishment.

The fire strategy guide (Figure 5) provides criteria for identification of Prescription, Escaped and Wildfires and actions for their management. Use of the guide assumes that fire management areas will be designated within the ponderosa pine and mixed conifer zones. Within each area the development of the fire management plan requires information on ecosystem characteristics, fuels, weather topography and resource management objectives.

FIGURE 5. Fire Strategy Guide for Ponderosa Pine and Mixed Conifer Ecosystems



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APPENDIX

Appendix A. Physical and Chemical Properties of Ponderosa Pine Slash and Non-slash Fuels.

Appendix A-1. Physical properties of ponderosa pine slash fuels.

Item	Units	Specifics	Source
Quadratic mean diameter (d^2q)			
0-0.24" size class	in^2	0.0248	Brown (1974); Brown-Roussopoulos (1974)
0.25-0.99" size class	in^2	0.3170	" " " " "
1.0-2.99" size class	in^2	2.8300	" " " " "
3.0" + size class (sound & rotten)[1/]	in^2	---	Brown (1974)
Specific gravity (s) and particle density (p_p)[2/]			
0-0.24" size class	g/cc lb/ft^3	.48 29.97	Brown (1974)
0.25-0.99" size class	" "	.48 29.97	" "
1.0-2.99" size class	" "	.40 24.97	" "
3.0" + sound size class	" "	.40 24.97	" "
3.0" + rotten size class	" "	.30 18.73	" "
needles (litter)		.51 31.84	Brown[3/]; Fosberg (1975)
duff		.47 29.34	Brown[3/];
Non-horizontal correction factor (a)[4/]			
0-0.24" size class	---	1.25	Brown (1974); Brown-Roussopoulos (1974)
0.25-0.99" size class	---	1.25	" " " " "
1.0-2.99" size class	---	1.22	" " " " "
3.0" size class (sound & rotten)	---	1.00	" " " " "
Surface area -to- volume ratio (σ)[5/]			
0-0.24" size class	ft^{-1}	260.0	Brown[3/]
0-25-0.99" size class	"	90.4	"
1.0-2.99" size class	"	29.9	"
3.0" + sound size class[6/]	"	---	"
3.0" + rotten size class[6/]	"	---	"
needles (litter)	"	1756.0	"
Bulk density (p_b)			
litter	lb/ft^3	0.986	Brown[3/]
duff	"	4.9	"
Moisture of extinction (M_x)	PDWB[7/]	.75	Brown (1972)

Appendix A-2. Physical properties of ponderosa pine non-slash fuels.

Item	Units	Specifics	Source
Quadratic mean diameter (d^2q)			
0-0.24" size class	in^2	0.0342	Brown (1974); Brown-Roussopoulos (1974)
0.25-0.99" size class	in^2	0.2380	" " " " "
1.0-2.99" size class	in^2	3.1200	" " " " "
3.0" + size class (sound & rotten)[1/]	in^2	---	Brown (1974)
Specific gravity (s) and particle density (p_p)[2/]			
0-0.24" size class	g/cc lb/ft3	.48 29.97	Brown (1974)
0.25-0.99" size class	" "	.48 29.97	" "
1.0-2.99" size class	" "	.40 24.97	" "
3.0" + sound size class	" "	.40 24.97	" "
3.0" + rotten size class	" "	.30 18.73	" "
needles (litter)	" "	.51 31.84	Brown[3/]; Fosberg (1975)
duff	" "	.47 29.34	" " "
Non-horizontal correction factor (a)[4/]			
0-0.24" size class	---	1.13	Brown (1974); Brown-Roussopoulus (1974)
0.25-0.99" size class	---	1.13	" " " " "
1.0-2.99" size class	---	1.13	" " " " "
3.0" size class (sound & rotten)	---	1.00	" " " " "
Surface area -to- volume ratio (σ)[5/]			
0-0.24" size class	ft^{-1}	260.0	Brown[3/]
0-25.0.99" size class	"	90.4	"
1.0-2.99" size class	"	29.9	"
3.0" + sound size class[6/]	"	---	"
3.0" + rotten size class[6/]	"	1756.0	"
Bulk density (p_b)			
litter	lb/ft^3	0.986	Brown[3/]
duff	"	4.9	"
Moisture of extinction (M_x)	PDWB[7/]	.25	Rothermel (1972)

Appendix A-3. Chemical Properties of Ponderosa Pine Fuels.

Item	Units	Specifics	Source
Low heat content (h)			
0-0.24" size class	Btu/lb	9260.0	Brown[1/]
0.25-0.99" size class	"	8800.0	"
1.0-2.99" size class	"	8800.0	"
3.0" + sound size class	"	8000.0	"
3.0" + rotten size class	"	8000.0	"
needles (litter)	"	8730.0	"
duff	"	8000.0	"
Mineral content (S_T)			
0-0.24" size class	PDWB[2/]	.0245	Brown[1/]
0.25-0.99" size class	"	.0219	"
1.0-2.99" size class	"	.0219	"
3.0" + sound size class	"	.0550	"
3.0" + rotten size class	"	.0550	"
needles (litter)	"	.0311	"
duff	"	---	"
Effective mineral content (S_e)			
0-0.24" size class	PDWB[2/]	.0120	Brown[1/]
0.25-0.99" size class	"	.0090	"
1.0-2.99" size class	"	.0090	"
3.0" + sound size class	"	.0100	"
3.0" + rotten size class	"	.0100	"
needles (litter)	"	.0160	"
duff	"	---	"

1/ Personal communication with James K. Brown, Principal Forest Fuels Scientist, USDA For. Serv. Intermt. For. and Range Exp. Stn. stationed at the North. For. Fire Lab., Missoula, Mont. Summary table of fuel element properties used are on file with the Fuels Science Work Unit. Dec. 20, 1977.

2/ Percent of Dry Weight Basis

Footnotes:

1/ The average diameter of all 3.0" + intersections is used.

2/ Particle density $p_p \approx 62.43 \times s$; taking the density of water at room temperature to equal 62.43 16/ft^3.

3/ Personal communication with James K. Brown, Principal Forest Fuels Scientist, USDA For. Ser. Intermt. For. and Range Exp. Stn. stationed at the North For. Fire Lab., Missoula, Mont. Summary table of fuel element properties used are on file with the Fuels Science Work Unit. Dec. 20, 1977.

4/ Not a physical fuel property; used for solving planar intersect equation (see Brown and Roussopoulos, 1974).

5/ Computed from the source given, where $\sigma = \frac{4}{d}$, d in feet.

6/ Computed after average diameter is determined for the sampling area.

7/ Percent of dry weight basis.

Appendix B. Mean Fuel, Litter, and Duff Depths, and Large Log Diameters of the Eagles Cliff Site.

Included in this appendix is information on the mean plot fuel depth (dead and live; five measurements per plot), and litter and duff depths (four measurements per plot). The mean plot diameter of all woody intersections (sound and rotten material) greater than 3.0 inches in diameter is also included. The mean and standard deviation are $\bar{X}$ and s, respectively. The "n" values under "3.0 inch + diameters" signifies the number of intersections per plot.

Appendix B-1.

Plot No.	Fuel Depth (Feet) dead		live		Litter Depth (inches)		Duff Depth (inches)		3.0" + Diameters (inches) sound			rotten		
	X̄	s	X̄	s	X̄	s	X̄	s	n	X̄	s	n	X̄	s
3	.11	.09	---	---	.10	0.00	.50	0.00	---	---	---	---	---	---
11a	2.00	1.42	---	---	.10	0.00	.10	0.00	7	7.29	4.34	---	---	---
11b	.65	.55	.03	.07	.10	0.00	1.30	.42	1	6.50	---	---	---	---
12	.14	.13	.28	.39	.10	0.00	.50	.14	6	4.17	1.17	---	---	---
14	.28	.32	---	---	.10	0.00	.35	.35	---	---	---	---	---	---
16	.47	.42	.16	.35	.10	0.00	1.05	.35	---	---	---	---	---	---
19a	.86	.34	---	---	.10	0.00	.55	.07	5	8.50	2.57	1	5	---
19b	.51	.26	---	---	.25	.07	1.25	.07	3	9.17	4.07	---	---	---
20	.31	.26	.03	.06	.10	0.00	1.35	.07	---	---	---	---	---	---
21	.20	.25	.07	.15	---	---	.05	.07	---	---	---	---	---	---
22	.58	.43	---	---	.05	.07	.40	.42	---	---	---	---	---	---
26	.48	.57	---	---	.10	0.00	1.85	1.06	---	---	---	---	---	---
27	.15	.09	.13	.18	.10	0.00	1.55	.07	---	---	---	---	---	---
28	.53	.22	.10	.22	.10	0.00	.55	.49	---	---	---	---	---	---
29	.78	.53	---	---	.20	0.00	2.45	.78	---	---	---	---	---	---
30a	2.47	.44	---	---	.10	0.00	1.05	.07	3	7.83	2.57	---	---	---
30b	1.20	.92	.10	.18	.10	0.00	4.55	1.34	4	6.80	2.01	---	---	---
32	.25	.16	.07	.17	.05	.07	.45	.21	---	---	---	---	---	---
33	.25	.16	.08	.17	.05	.07	.85	.50	---	---	---	---	---	---
34	.30	.25	.25	.56	.25	.07	3.75	.78	---	---	---	---	---	---
35	.22	.27	---	---	.10	0.00	1.70	.85	1	3.50	---	---	---	---
40	.10	.04	.05	.11	.15	.07	2.60	.14	---	---	---	---	---	---
41	.14	.04	---	---	.15	.07	1.55	1.34	1	13.00	---	---	---	---
42	.12	.08	---	---	.10	0.00	.80	0.00	---	---	---	---	---	---
43	.25	.34	.05	.11	.15	.07	.30	.42	---	---	---	---	---	---
44	.22	.22	.10	.22	.10	0.00	.35	.21	---	---	---	---	---	---

Appendix B-2.

	Fuel Depth (Feet)				Litter Depth (inches)		Duff Depth (inches)		3.0" + Diameters (inches)					
	dead		live						sound			rotten		
Plot No.	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	n	$\bar{X}$	s	n	$\bar{X}$	s
3	---	---	---	---	---	---	---	---	---	---	---	---	---	---
11a	---	---	---	---	---	---	---	---	4	8.5	3	---	---	---
11b	---	---	---	---	---	---	---	---	---	---	---	---	---	---
12	---	---	---	---	---	---	---	---	1	6.0	---	---	---	---
14	.01	.02	---	---	.05	.07	.10	.14	---	---	---	---	---	---
16	---	---	---	---	---	---	---	---	---	---	---	---	---	---
19a	---	---	---	---	---	---	---	---	3	9.17	1.61	---	---	---
19b	---	---	---	---	---	---	---	---	3	7.67	3.69	---	---	---
20	---	---	---	---	---	---	---	---	---	---	---	---	---	---
21	.01	.02	---	---	---	---	---	---	---	---	---	---	---	---
22	.01	.02	---	---	---	---	---	---	---	---	---	---	---	---
26	.03	.03	---	---	---	---	---	---	---	---	---	---	---	---
27	.03	.02	.01	.02	.10	0.00	1.10	.42	---	---	---	---	---	---
28	.07	.02	---	---	---	---	.05	.07	---	---	---	---	---	---
29	.01	.02	---	---	---	---	1.80	.99	---	---	---	---	---	---
30a	---	---	---	---	---	---	---	---	1	9.00	---	---	---	---
30b	---	---	---	---	---	---	---	---	4	6.38	1.89	---	---	---
32	---	---	---	---	.10	0.00	.10	0.00	---	---	---	---	---	---
33	---	---	---	---	.05	.07	.10	0.00	---	---	---	---	---	---
34	.03	.03	---	---	.10	0.00	.10	0.00	---	---	---	---	---	---
35	.04	.03	---	---	.10	0.00	.25	.07	---	---	---	---	---	---
40	.03	.02	---	---	---	---	1.15	1.62	---	---	---	---	---	---
41	---	---	---	---	.10	0.00	1.65	.78	---	---	---	---	---	---
42	.05	.02	---	---	.10	0.00	.80	0.00	---	---	---	---	---	---
43	.05	.01	---	---	.20	0.00	.50	.14	---	---	---	---	---	---
44	.03	.02	---	---	---	---	.25	.07	---	---	---	---	---	---

Appendix B-3.

	Fuel Depth (feet)				Litter Depth (inches)		Duff Depth (inches)		3.0" + Diameters (inches)					
	dead		live						sound			rotten		
Plot No.	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	n	$\bar{X}$	s	n	$\bar{X}$	s
3	.06	.06	.17	.16	.73	.53	.33	.33	---	---	---	---	---	---
11*	.34	.40	.67	.14	.37	.31	.13	.10	5	7.60	2.70	---	---	---
12*	.46	.69	.49	.40	.25	.13	.02	.05	1	6.00	---	---	---	---
14	.17	.20	.25	.26	.28	.10	.07	.10	---	---	---	---	---	---
16	.05	.06	.15	.19	.27	.10	.07	.10	---	---	---	---	---	---
19*	.10	.09	.47	.32	.45	.31	.07	.10	2	7.00	1.41	---	---	---
20	.07	.09	.15	.13	.43	.17	.07	.10	---	---	---	---	---	---
21	.24	.29	.67	.33	.20	.08	.07	.10	---	---	---	---	---	---
22	.12	.10	.28	.10	.43	.21	.10	.08	---	---	---	---	---	---
26	.41	.40	.28	.18	.25	.13	.08	.10	---	---	---	---	---	---
27	.06	.06	.29	.09	.35	.19	.10	.14	---	---	---	---	---	---
28	.14	.08	.40	.23	.15	.13	.03	.05	---	---	---	---	---	---
29	.07	.09	.67	.53	.25	.06	.08	.10	---	---	---	---	---	---
30*	.18	.23	.36	.27	.35	.13	.13	.10	2	11.0	2.83	---	---	---
32	.09	.12	.02	.05	.23	.05	.10	.08	---	---	---	---	---	---
33	.30	.67	.13	.15	.45	.24	.20	.28	---	---	---	---	---	---
34	.30	.47	.54	.29	.30	.12	.13	.10	---	---	---	---	---	---
35	.26	.29	.42	.26	.63	.42	.20	0.00	---	---	---	---	---	---
40	.05	.03	.06	.09	.60	.42	.25	.21	---	---	---	---	---	---
41	.05	.03	.08	.13	.73	.41	.55	.42	---	---	---	---	---	---
42	.10	.09	.54	.58	.73	.25	.45	.19	---	---	---	---	---	---
43	.04	.03	.10	.15	.50	.29	.13	.15	---	---	---	---	---	---
44	.04	.05	.10	.20	.68	.33	.08	.05	---	---	---	---	---	---

*denotes slash plot

Appendix C. Downed Woody Intersections and Sampling Plane Information of the Eagles Cliff Site.

This appendix contains a tally by plot of the following:

(1) The number of intersections in the four size classes less than 2.99 inches in diameter;

(2) The diameters of sound and rotten woody material greater than 3.0 inches in diameter;

(3) The sampling plane direction (in degrees);

(4) The slope (in percent) of the planar transect line from which the intersections of (1) and (2) were tallied.

The length of the planar transect lines used to determined the intersections are as follows:

(1) 0-0.24" size class:	6 feet (pre and post-fire slash fuels)
	12 feet (pre and post-fire non-slash fuels)
	10 feet (2nd year all fuel types)
(2) 0.25-0.99" size class:	6 feet (pre and post-fire slash fuels)
	12 feet (pre and post-fire non-slash fuels)
	30 feet (2nd year all fuel types)
(3) 1.0-2.99" size class:	10 feet (pre and post-fire slash fuels)
	15 feet (pre and post-fire non-slash fuels)
	50 feet (2nd year all fuel types)
(4) 3.0" + (sound and rotten):	35 feet (pre and post-fire slash fuels)
	50 feet (pre and post-fire non-slash fuels)
	50 feet (2nd year all fuel types)

Appendix C-1.

Plot No.	Sampling Plane Direction (degrees)	Planar Slope (%)	No. of Intersections by Size Class 0-0.24"	0.25-0.99"	1.0-2.99"	Diameters of 3.0" + Material 3.0" + sound	3.0" + rotten
3	80	44	11	8	---	---	---
11a	178	35	5	32	9	5.0,9.0,13.0,3.5,3.5,13.0,4.0	---
11b	20	35	9	23	5	6.5	---
12	46	36	2	5	1	6.0,4.0,3.0,5.0,3.0,4.0	---
14	72	43	3	---	---	---	---
16	186	41	2	---	---	---	---
19a	121	32	8	18	2	5.5,9.5,6.5,9.0,12.0	5.0
19b	215	32	10	17	6	4.5,11.0,12.0	---
20	230	37	2	1	---	---	---
21	84	36	1	3	---	---	---
22	210	34	---	1	---	---	---
26	72	33	6	---	---	---	---
27	268	33	12	2	---	---	---
28	277	32	2	---	---	---	---
29	337	26	1	9	---	---	---
30a	89	31	6	28	2	10.0,5.0,8.5	---
30b	245	31	14	42	3	5.2,9.0,8.0,5.0	---
32	67	39	5	3	---	---	---
33	67	39	7	4	---	---	---
34	282	37	4	4	1	---	---
35	276	41	2	---	---	3.5	---
40	188	27	8	2	---	---	---
41	95	22	9	1	1	13.0	---
42	105	11	1	---	---	---	---
43	17	40	1	1	---	---	---
44	126	44	---	2	---	---	---

Plot No.	Sampling Plane Direction (degrees)	Planar Slope (%)	No. of Intersections by Size Class: 0-0.24"	0.25-0.99"	1.0-2.99"	Diameters of 3.0" + Material: 3.0" + sound	3.0" + rotten
3	80	44	.0236	---	---	---	---
11a	178	35	---	---	---	5.0,7.0,11.0,11.0	---
11b	20	35	---	---	---	---	---
12	46	36	---	---	---	6.0	---
14	72	43	1	---	---	---	---
16	186	41	---	---	---	---	---
19a	121	32	---	---	---	8.5,8.0,11.0	---
19b	215	32	---	---	---	3.5,9.0,10.5	---
20	230	37	1	---	---	---	---
21	84	36	1	---	---	---	---
22	210	34	1	---	---	---	---
26	72	33	4	---	---	---	---
27	268	33	---	---	---	---	---
28	277	32	---	1	---	---	---
29	337	26	---	---	1	---	---
30a	89	31	---	---	---	9.0	---
30b	245	31	---	---	---	9.0,6.5,5.0,5.0	---
32	67	39	---	1	---	---	---
33	67	39	---	2	---	---	---
34	282	37	---	---	---	---	---
35	276	41	---	---	---	---	---
40	188	27	---	---	---	---	---
41	95	22	---	---	---	---	---
42	105	11	3	---	---	---	---
43	17	40	---	---	---	---	---
44	126	44	1	1	---	---	---

Appendix C-3

Plot No.	Sampling Plane Direction (degrees)	Planar Slope (%)	No. of Intersections by Size Class			Diameters of 3.0" + Material	
			0.0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten
3	120	5	3	5	---	---	---
11*	160	20	---	---	2	5.0,6.0,11.0,10.0,6.0	---
12*	120	30	---	1	1	6.0	---
14	95	30	4	7	---	---	---
16	102	5	2	6	---	---	---
19*	120	25	4	8	1	6.0,8.0	---
20	114	20	1	4	---	---	---
21	125	30	1	3	---	---	---
22	92	5	1	3	---	---	---
26	322	15	4	3	---	---	---
27	308	20	3	7	---	---	---
28	312	30	6	2	1	---	---
29	134	20	1	9	---	---	---
30*	126	15	2	5	---	9.0,13.0	---
32	166	5	---	4	---	---	---
33	164	5	1	8	2	---	---
34	134	30	5	25	1	---	---
35	132	25	4	16	3	---	---
40	140	15	2	3	1	---	---
41	160	15	---	6	---	---	---
42	158	15	8	16	---	---	---
43	80	10	2	5	---	---	---
44	104	35	2	7	---	---	---

*denotes slash plot

Appendix D. Mean Fuel, Litter, and Duff Depths, and Large Log Diameters of the Mill Creek Site.

Included in this appendix is information on the mean plot fuel depth (dead and live; six measurements per plot), and litter and duff depths (four measurements per plot). The mean plot diameter of all woody intersections (sound and rotten material) greater than 3.0 inches in diameter is also included. The mean and standard deviation are $\bar{X}$ and s, respectively. The "n" values under "3.0 inch + diameters" signifies the number of intersections per plot.

Appendix D-1.

	Fuel Depth (feet)				Litter Depth (inches)		Duff Depth (inches)		3.0" + Diameters (inches)					
	dead		live						sound			rotten		
Plot No.	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	n	$\bar{X}$	s	n	$\bar{X}$	s
Pre-fire														
1	.08	.07	.21	.22	.75	.24	.70	.42	---	---	---	---	---	---
2	.35	.24	.61	.56	.30	.26	.15	.13	---	---	---	---	---	---
3	.26	.20	.52	.54	.25	.06	.18	.10	---	---	---	---	---	---
4	.13	.06	.15	.12	.50	.29	.20	.14	---	---	---	---	---	---
5	.24	.19	.58	.54	.28	.15	1.00	.74	---	---	---	---	---	---
6	.08	.06	.46	.59	.50	.36	.75	.79	---	---	---	---	---	---
Post-fire														
1	.01	.01	.01	.01	---	---	---	---	---	---	---	---	---	---
2	.35	.24	.61	.56	.30	.26	.15	.13	---	---	---	---	---	---
3	.03	.03	---	---	---	---	.15	.28	---	---	---	---	---	---
4	.01	.02	---	---	---	---	.13	.14	---	---	---	---	---	---
5	.02	.02	---	---	---	---	.07	.12	---	---	---	---	---	---
6	.02	.01	.01	.02	---	---	.18	.19	---	---	---	---	---	---
1st year post-fire														
1	.05	.06	.12	.16	.50	.27	.35	.39	---	---	---	1	3.0	---
2	.21	.20	.15	.19	.28	.10	.13	.10	---	---	---	---	---	---
3	.20	.09	.21	.11	.33	.13	.43	.24	---	---	---	---	---	---
4	.07	.13	.21	.22	.45	.19	.28	.26	---	---	---	---	---	---
5	.11	.16	.14	.13	.30	.12	.53	.40	---	---	---	---	---	---
6	.26	.26	.28	.17	.35	.13	.35	.41	---	---	---	---	---	---

Appendix E. Downed Woody Intersections and Sampling Plane Information of the Mill Creek Site.

This appendix contains a tally by plot of the following:

(1) The number of intersections in the four size classes less than 2.99 inches in diameter;

(2) The diameters of sound and rotten woody material greater than 3.0 inches in diameter;

(3) The sampling plane direction (in degrees);

(4) The slope (in percent) of the planar transect line from which the intersections of (1) and (2) were tallied.

The length of the planar transect lines used to determine the intersections are as follows:

(1) 0-0.24" size class	10 feet (all fuel types)
(2) 0.25-0.99" size class	10 feet (all fuel types)
(3) 1.0-2.99" size class	30 feet (all fuel types)
(4) 3.0" + (sound & rotten):	50 feet (all fuel types)

Appendix E-1.

Plot No.	Sampling Plane Direction (degrees)	Planar Slope (%)	No. of Intersections by Size Class: 0.0.24"	0.25-0.99"	1.0-2.99"	Diameters of 3.0" + Material: 3.0" + sound	3.0" + rotten
Pre-fire							
1	90	6	15	7	2	---	---
2	90	1	5	7	2	---	---
3	300	37	25	7	1	---	---
4	330	19	1	3	---	---	---
5	30	17	13	2	1	---	---
6	60	4	9	6	---	---	---
Post-fire							
1	90	6	13	1	---	---	---
2	90	1	---	---	---	---	---
3	300	37	16	3	---	---	---
4	330	19	6	3	---	---	---
5	30	17	9	---	1	---	---
6	60	4	3	1	---	---	---
1st year post-fire							
1	90	6	6	10	---	---	3.0
2	90	1	19	17	3	---	---
3	300	37	22	5	3	---	---
4	330	19	10	6	---	---	---
5	30	17	14	13	---	---	---
6	60	4	9	10	1	---	---

Appendix F. Fuel Loading Contributed by Shrub Components of the Mill Creek Site.

Included in this appendix are the fuel loadings (in tons per acre) by plot contributed by the following shrub components:

(1) Total aboveground weight;

(2) Total branchwood weight by size class;

(3) Total leaf weight.

Appendix F-1.

Plot No.	Species	Category	Total Leaf Weight	Fuel Loading Contributed by Shrub Components (Tons/Acre): Total Branchwood Weight 0-0.50 cm	0.51-2.00 cm	2.01-5. + cm	Total Aboveground Weight
1.1	bitterbrush	dead	.0927	.1103	.1748	.0289	.4066
		live	.8338	.9924	1.5731	.2598	3.6592
1.2	bitterbrush	dead	.1568	.4166	.4736	.3010	1.3479
		live	.6273	1.6662	1.8943	1.2039	5.3918
2.1	---	---	---	---	---	---	---
2.2	bitterbrush	dead	---	---	---	---	---
		live	.0328	.0873	.0367	---	.1568
3.1	big sagebrush	dead	.0330	.0835	.0835	.0607	.2607
		live	.2970	.7511	.7511	.5467	2.3460
3.2	bitterbrush	dead	.0346	.1114	.1215	.0709	.3384
		live	.6575	2.1159	2.3087	1.3471	6.4292
4.1	bitterbrush	dead	.0831	.1839	.3178	---	.5848
		live	.3322	.7358	1.2713	---	2.3393
4.2	big sagebrush	dead	.2159	.5335	.5694	.3566	1.6753
		live	1.2234	3.0229	3.2266	2.0205	9.4934
5.1	bitterbrush	dead	.0390	.0891	.0774	---	.2053
		live	.1558	.3562	.3096	---	.8211
5.2	---	---	---	---	---	---	---
6.1	bitterbrush	dead	---	---	---	---	---
		live	2.0074	5.9370	6.6381	3.5739	18.1564
6.2	bitterbrush	dead	---	---	---	---	---
		live	.2474	.5586	.8640	---	1.6700

Appendix F-2.

Plot No.	Species	Category	Fuel Loading Contributed by Shrub Components (Tons/Acre): Total Leaf Weight	Total Branchwood Weight: 0-0.50 cm	Total Branchwood Weight: 0.51-2.00 cm	Total Branchwood Weight: 2.01-5. + cm	Total Aboveground Weight
1.1	bitterbrush	dead	.9666	1.2756	1.6357	.5685	4.4464
		live	.5205	.6869	.8807	.3061	2.3942
1.2	bitterbrush	dead	.0966	.2325	.3301	.0660	.7253
		live	.3865	.9302	1.3205	.2642	2.9014
2.1	---	---	---	---	---	---	---
2.2	bitterbrush	dead	.2837	.6683	.8293	.2973	2.0786
		live	---	---	---	---	---
3.1	big sagebrush	dead	.0330	.0835	.0835	.0607	.2607
		live	.2970	.7511	.7511	.5467	2.3460
3.2	bitterbrush	dead	.0346	.1114	.1215	.0709	.3384
		live	.6575	2.1159	2.3087	1.3471	6.4292
4.1	bitterbrush	dead	.0437	.0923	.1447	---	.2807
		live	.3932	.8307	1.3027	---	2.5266
4.2	big sagebrush	dead	1.0555	2.6691	2.8729	1.6343	8.2324
		live	.0215	.0545	.0586	.0334	.1680
5.1	bitterbursh	dead	.0066	.0149	.0130	---	.0346
		live	.0266	.0597	.0522	---	.1384
5.2	---	---	---	---	---	---	---
6.1	bitterbrush	dead	.0168	.0360	.0538	---	.1066
		live	.3197	.6846	1.0213	---	2.0256
6.2	---	---	---	---	---	---	---

Appendix G. Shrub Component Weights of the Mill Creek Site.

This appendix contains individual shrub information by plot of the following:

(1) Basal stem diameter (in centimeters) of each tallied shrub;

(2) Percent of shrub that is dead;

(3) Total aboveground weight;

(4) Total leaf weight;

(5) Total branchwood weight by size class and the fractional contribution of the total for each size class.

Appendix G-1.

Plot No.	Percent Dead	Species	Basal Stem Diameter	Shrub Weight by Components (Tons/Acre): Total Leaf Weight	Total Branchwood Weight: 0-0.50 cm	0.51-2.00 cm	2.01-5.+ cm	Total Aboveground Weight	Fractional Contribution: 0-0.50	0.51-2.00	2.01 +
1.1	10	bitterbrush	1.6669	.1031	.2113	.3652	---	.6796	.3666	.6334	---
	"	"	1.8256	.1279	.2760	.4770	---	.8809	.3666	.6334	---
	"	"	1.4288	.0717	.1342	.2319	---	.4378	.3666	.6334	---
	"	juniper	2.5400	.6238	.4812	.6738	.2887	2.0675	.3333	.4667	.2000
1.2	20	bitterbrush	1.6669	.1031	.2113	.3652	---	.6796	.3666	.6334	---
	"	"	1.0319	.0332	.0746	.0652	---	.1730	.5333	.4667	---
	"	"	1.0319	.0332	.0746	.0652	---	.1730	.5333	.4667	---
	"	"	.8731	.0224	.0510	.0340	---	.1074	.6000	.4000	---
	"	"	3.4925	.5922	1.6713	1.8383	1.5049	5.6067	.3333	.3666	.3001
2.1	---	---	---	---	---	---	---	---	---	---	---
2.2	0	bitterbrush	.9525	.0275	.0735	.0367	---	.1377	.6667	.3333	---
	"	"	.4763	.0053	.0138	---	---	.0191	1.0000	---	---
3.1	10	big sagebrush	4.2069	.3300	.8346	.8346	.6074	2.6067	.3666	.3666	.2668
3.2	5	bitterbrush	3.7306	.6921	2.2273	2.4302	1.4180	6.7676	.3666	.4000	.2334
4.1	20	bitterbrush	2.0638	.1708	.3956	.6834	---	1.2498	.3666	.6334	---
	"	"	1.9050	.1414	.3128	.5405	---	.9947	.3666	.6334	---
	"	"	1.6669	.1031	.2113	.3652	---	.6796	.3666	.6334	---
4.2	15	bitterbrush	1.5081	.0814	.1690	.2604	---	.5108	.3936	.6064	---
	15	big sagebrush	3.1750	.1940	.4374	.4772	.2784	1.3870	.3666	.4000	.2334
	"	"	4.0481	.3069	.7641	.7641	.5561	2.3913	.3666	.3666	.2668
	"	"	5.4769	.5431	1.5274	1.5274	1.1116	4.7094	.3666	.3666	.2668
	"	"	3.1750	.1940	.4374	.4772	.2784	1.3870	.3666	.4000	.2334
	"	"	2.4606	.1199	.2211	.2897	.1526	.7832	.3333	.4367	.2300
5.2	---	---	---	---	---	---	---	---	---	---	---

Appendix C-1. (con't)

Plot No.	Percent Dead	Species	Basal Stem Diameter	Total Leaf Weight	Total Branchwood Weight 0-0.50 cm	0.51-2.00 cm	2.01-5.+ cm	Total Aboveground Weight	Fractional Contribution 0-0.50	0.51-2.00	2.01 +
			Shrub Weight by Components (Tons/Acre)								
6.1	0	bitterbrush	3.8100	.7274	2.3679	2.5836	1.5076	7.1865	.3666	.4000	.2334
	"	"	2.6988	.3220	.8670	1.0247	.4732	2.6869	.3666	.4333	.2001
	"	"	3.1750	.4728	1.3927	1.5196	.8867	4.2718	.3666	.4000	.2334
	"	"	1.5875	.0919	.1998	.2996	---	.5913	.4000	.6000	---
	"	"	2.9369	.3933	1.1096	1.2106	.7064	3.4199	.3666	.4000	.2334
6.2	0	bitterbrush	2.0638	.1708	.3956	.6834	---	1.2498	.3666	.6334	---
	"	"	1.2700	.0542	.1120	.1466	---	.3128	.4330	.5670	---
	"	"	.8731	.0224	.0510	.0340	---	.1074	.6000	.4000	---

Appendix G-2.

Plot No.	Percent Dead	Species	Basal Stem Diameter	Shrub Weight by Components (Tons/Acre): Total Leaf Weight	Total Branchwood Weight: 0-0.50 cm	0.51-2.00 cm	2.01-5.+ cm	Total Aboveground Weight	Fractional Contribution: 0-0.50	0.51-2.00	2.01 +
1.1	65	bitterbrush	1.8256	.1279	.2760	.4770	---	.8809	.3666	.6334	---
	"	"	1.9050	.1414	.3128	.5405	---	.9947	.3666	.6334	---
	"	Juniper	3.8100	1.2178	1.3737	1.4989	.8746	4.9650	.3666	.4000	.2334
1.2	20	bitterbrush	2.5400	.2791	.7262	.9245	.3302	2.2601	.3666	.4667	.1667
	"	"	1.9050	.1414	.3128	.5405	---	.9947	.3666	.6334	---
	"	"	1.3494	.0626	.1237	.1856	---	.3719	.4000	.6000	---
2.1	---	---	---	---	---	---	---	---	---	---	---
2.2	100	bitterbrush	2.3019	.2211	.5446	.6437	.2973	1.7067	.3666	.4333	.2001
	"	"	1.3494	.0626	.1237	.1856	---	.3719	.4000	.6000	---
3.1	10	Big sagebrush	4.2069	.3300	.8346	.8346	.6074	2.6067	.3666	.3666	.2668
3.2	5	bitterbrush	3.7306	.6921	2.2273	2.4302	1.4180	6.7676	.3666	.4000	.2334
4.2	98	big sagebrush	1.8256	.0682	.1220	.2109	---	.4011	.3666	.6334	---
	"	"	1.8256	.0682	.1220	.2109	---	.4011	.3666	.6334	---
	"	bitterbrush	1.3494	.0620	.1237	.1856	---	.3719	.4000	.6000	---
	"	big sagebrush	.8731	.0170	.0358	.0239	---	.0767	.6000	.4000	---
	"	"	.7144	.0116	.0286	.0087	---	.0489	.7666	.2334	---
	"	"	5.4769	.5431	1.5274	1.5274	1.1116	4.7094	.3666	.3666	.2668
	"	"	4.0481	.3069	.7641	.7641	.5561	2.3913	.3666	.3666	.2668
4.1	10	bitterbrush	1.8256	.1279	.2760	.4770	---	.8809	.3666	.6334	---
	"	"	1.5875	.0919	.1998	.2996	---	.5913	.4000	.6000	---
	"	"	1.3494	.0626	.1237	.1856	---	.3719	.4000	.6000	---
	"	"	1.3494	.0626	.1237	.1856	---	.3719	.4000	.6000	---
	"	"	1.5875	.0919	.1998	.2996	---	.5913	.4000	.6000	---

Appendix G-2. (con't).

Plot No.	Percent Dead	Species	Basal Stem Diameter	Shrub Weight by Components (Tons/Acre): Total Leaf Weight	Total Branchwood Weight: 0-0.50 cm	0.51-2.00 cm	2.01-5.+ cm	Total Aboveground Weight	Fractional Contribution: 0.0.50	0.51-2.00	2.01 +
5.1	20	bitterbrush	1.0319	.0332	.0746	.0652	---	.1730	.5333	.4667	---
5.2	---	---	---	---	---	---	---	---	---	---	---
6.1	5	bitterbrush	.7938	.0179	.0405	.0234	---	.0818	.6333	.3667	---
	"	"	1.3494	.0626	.1237	.1856	---	.3719	.4000	.6000	---
	"	"	1.5081	.0814	.1690	.2604	---	.5108	.3936	.6064	---
	"	"	1.0319	.0332	.0746	.0652	---	.1730	.5333	.4667	---
	"	"	1.9050	.1414	.3128	.5405	---	.9947	.3666	.6334	---
6.2	---	---	---	---	---	---	---	---	---	---	---

Appendix H. Shrub Inventory Data of the Mill Creek Site.

This appendix provides the raw shrub inventory data by plot of the following:

(1) Shrub species (common name);
(2) Basal stem diameter (in centimeters) of each tallied shrub;
(3) Average shrub height (in centimeters);
(4) Percent cover of each plot.

Two one-fourth milacre subplots per plot were used to inventory shrubs.

Appendix H-1.

Plot No.	Percent Cover	Percent Dead	Species	Basal Stem Diameter (cm)	Average Shrub Height (cm)
1.1	50	10	bitterbrush	1.67	30.5
			bitterbrush	1.83	35.6
			bitterbrush	1.43	22.9
			common juniper	2.54	25.4
1.2	50	20	bitterbrush	1.67	22.9
			"	1.03	10.2
			"	1.03	10.2
			"	.87	12.7
			"	3.49	38.1
2.1	---	---	---	---	---
2.2	10	0	bitterbrush	.95	25.4
			bitterbrush	.48	15.2
3.1	80	10	big sagebrush	4.21	38.1
3.2	15	5	bitterbrush	3.73	35.6
4.1	20	20	bitterbrush	2.06	35.6
			"	1.91	35.6
			"	1.67	22.9
4.2	40	15	bitterbrush	1.51	22.9
			big sagebrush	3.18	35.6
			"	4.05	38.1
			"	5.48	38.1
			"	3.18	35.6
			"	2.46	25.4
5.1	25	20	bitterbrush	1.03	25.4
			"	.79	7.6
			"	.87	10.2
			"	1.27	22.9
			"	1.11	27.9
			"	.95	15.2

Appendix H-1. (con't).

Plot No.	Percent Cover	Percent Dead	Species	Basal Stem Diameter (cm)	Average Shrub Height (cm)
5.2	---	---	---	---	---
6.1	45	0	bitterbrush	3.81	33.0
			"	2.70	48.3
			"	3.18	17.8
			"	1.59	7.6
			"	2.94	10.2
6.2	35	0	bitterbrush	2.06	30.5
			"	1.27	25.4
			"	.87	20.3

Appendix H-2.

Plot No.	Percent Cover	Percent Dead	Species	Basal Stem Diameter (cm)	Average Shrub Height (cm)
1.1	40	65	bitterbrush	1.83	35.6
			"	1.91	25.4
			common juniper	3.81	20.3
1.2	30	20	bitterbrush	2.54	35.6
			"	1.91	10.2
			"	1.35	5.1
2.1	---	---	---	---	---
2.2	10	100	bitterbrush	2.30	25.4
			"	1.35	15.2
3.1	40	10	bitterbrush	4.21	38.1
3.2	15	5	bitterbrush	3.73	35.6
4.1	20	10	bitterbrush	1.83	33.0
			"	1.59	20.3
			"	1.35	30.5
			"	1.35	12.7
			"	1.59	33.0
4.2	5	98	bitterbrush	1.35	20.3
			big sagebrush	1.83	22.9
			"	1.83	22.9
			"	.87	10.2
			"	.71	7.6
			"	5.48	38.1
			"	4.05	38.1
5.1	20	20	bitterbrush	1.03	25.4
5.2	---	---	---	---	---
6.1	25	5	bitterbrush	.79	10.2
			"	1.35	27.9
			"	1.51	7.6
			"	1.03	5.1
			"	1.91	30.5
6.2	---	---	---	---	---

Appendix I. Summary Data From Study Plots, Weather and Fuel Moisture Measurements, Mill Creek Prescribed Fire.

Table I-1. Fuel loadings and fire behavior descriptors of the Mill Creek prescribed fire (approx. 2 acres).

Plot No.	Fuel Loading		Fire Behavior Descriptors			
	Prefire Fuel Load (tons/acre)	Fuel Consumed (tons/acre)	Linear Rate of Spread (feet/minute)	Flame Length (feet)	Byram's Intensity (BTU/fireline foot second)	Total Heal Release (BTU/square foot)
1	16.3461	11.2120	7.4	4.4	142.1	3014.9
2	4.5156	---	15.5	4.5	149.2	342.1
3	8.8457	2.0087	5.5	2.5	41.6	855.2
4	9.9809	3.1496	3.3	2.5	28.5	1242.3136
5	11.0608	9.6320	7.7	4.6	156.5	3567.9
6	18.6218	15.7183	7.2	4.8	171.7	5835.1

Table I-2. Fuel loading by ground and surface fuel components of the Mill Creek prescribed fire site.

	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	duff	live	dead	Loading
Pre-fire										
1	.3246	1.0547	1.0972	---	---	2.3170	6.2253	.0136	.0355	16.3461
2	.1080	1.0529	1.0953	---	---	.6742	1.3340	.0283	.1445	4.5156
3	.5758	1.1226	.5838	---	---	.1777	1.5563	.0872	.0889	8.8457
4	.0220	.4593	---	---	---	.7406	1.7787	.0366	.0468	9.9809
5	.2848	.3051	.5555	---	---	.4105	8.8933	.0517	.0661	11.0608
6	.1946	.9031	---	---	---	.7886	6.6700	.0573	.0950	18.6218
Post-fire										
1	.2813	.1507	---	---	---	---	---	---	---	5.1341
2	.1080	1.0529	1.0953	---	---	.6742	1.3340	.0283	.1445	5.3346
3	.3685	.4811	---	---	---	---	1.3340	---	---	6.8370
4	.1319	.4593	---	---	---	---	1.1858	---	---	6.8313
5	.1972	---	.5555	---	---	---	.5929	---	---	1.4288
6	.0649	.1505	---	---	---	---	1.6304	---	---	2.9035
1st year post-fire										
1	.1298	1.5067	---	---	.6302	.6563	3.1127	.0327	.0008	10.7713
2	.4104	2.5569	1.6429	---	---	.9011	1.7787	.1360	.0114	8.3348
3	.5067	.8018	1.7516	---	---	.4092	3.7797	.3013	.0163	12.2200
4	.2199	.9185	---	---	---	.3196	2.4457	.0371	.0010	8.9961
5	.3067	1.9833	---	---	---	.5492	2.6680	.0833	.0070	5.6807
6	.1946	1.5052	.5480	---	---	.4544	3.1127	.1217	.0256	7.0199

1/ Shrub loading included in total loading

Table I-3. Pre-fire fuel loading contributed by shrub components of the Mill Creek prescribed fire site.

			Fuel Loading Contributed by Shrub Components (Tons/Acre)				
			Total Leaf	Total Branchwood Weight			Total Aboveground
Plot No.	Species	Category	Weight	0-0.50 cm	0.51-2.00 cm	2.01 cm +	Weight
1	bitterbrush	dead	---	.2635	.3242	.1650	.7527
		live	.7556	1.3293	1.7337	.7319	4.5255
2	bitterbrush	dead	---	---	---	---	---
		live	.0164	.0437	.0184	---	.0784
3	bitterbrush	dead	---	.0975	.1025	.0658	.2658
		live	.4773	1.4335	1.5299	.9469	4.3876
4	big sagebrush	dead	---	.3587	.4436	.1783	.9806
		live	.7778	1.8794	2.2490	1.0103	5.9164
5	bitterbrush	dead	---	.0446	.0387	---	.0833
		live	.0779	.1781	.1548	---	.4106
6	bitterbrush	dead	---	---	---	---	---
		live	1.1274	3.2478	3.7511	1.7870	9.9132

Table I-4. Post-fire fuel loading contributed by shrub components of the Mill Creek prescribed fire site.

Plot No.	Species	Category	Fuel Loading Contributed by Shrub Components (Tons/Acre) Total Leaf Weight	Total Branchwood Weight 0-0.50 cm	0.51-2.00 cm	2.01 cm +	Total Aboveground Weight
1	bitterbrush	dead	---	.7541	.9829	.3173	2.0543
		live	.4535	.8086	1.1006	.2852	2.6478
2	bitterbrush	dead	---	.3342	.4147	.1487	.8974
		live	---	---	---	---	---
3	bitterbrush	dead	---	.0975	.1025	.0658	.2658
		live	.4773	1.4335	1.5299	.9469	4.3876
4	big sagebrush	dead	---	1.3807	1.5088	.8172	3.7070
		live	.2074	.4426	.6807	.0167	1.3473
5	bitterbrush	dead	---	.0075	.0065	---	.0140
		live	.0133	.0299	.0261	---	.0692
6	bitterbrush	dead	---	.0180	.0269	---	.0449
		live	.1599	.3423	.5107	---	1.0128

Table I-5. Fuel Moisture and Weather Data During the Mill Creek prescribed Burn (October 14, 1976).

Date	Time of Day	Plot No.	Weather Variables: Temperature °F	Relative Humidity percent	Wind Velocity mph	Fuel Moisture (%) by Surface and Ground Fuel Components: Downed Woody 0.0-0.24"	0.25-0.99"	1.0-2.99"	Litter	Herbaceous Vegetation Dead	Live	Shurbs Bitterbrush	Sagebrush
10-14-76	1200	---	60	20	2-7	6.6	7.2	---	12.5	5.4	56.5	81.2	68.1
	1215	2	61	18	2-7	---	---	---	---	---	---	---	---
	1330	1	59	21	2-12	---	---	---	---	---	---	---	---
	1345	3	60	20	2-8	---	---	---	---	---	---	---	---
	1414	6	60	20	2-10	---	---	---	---	---	---	---	---
	1454	5	63	18	2-6	---	---	---	---	---	---	---	---
	1511	4	61	20	2-7	---	---	---	---	---	---	---	---

Appendix J. Summary Data From Study Plots, Weather and Fuel Moisture Measurements, Eagles Cliff Prescribed Fire.

Table J-1. Fuel loadings and fire behavior descriptors of the Eagles Cliff prescribed fire (approx. 35 acres).

	FUEL LOADING		FIRE BEHAVIOR DESCRIPTORS			
Plot No.	Prefire Fuel Load (tons/acre)	Fuel Consumed (tons/acre)	Linear Rate of Spread (feet/minute)	Flame Length (feet)	Byram's Intensity (BTU/fireline foot second)	Total Heat Release (BTU/square feet)
3	6.6586	4.4123	14.2	8.5	594.8	1700.1
11*	67.7897	45.5090	11.5	25.5	6479.8	17604.5
19*	72.8171	40.6225	13.8	15.6	2226.5	15521.2
20	13.1138	13.0908	1.5	2.5	41.6	4837.0
26	18.2360	17.2557	4.9	4.5	149.2	6384.6
27	15.9094	6.0459	7.0	6.5	332.0	2267.4
28	5.8248	5.2222	16.7	12.2	1304.7	2001.7
30*	71.2161	53.5013	31.0	27.1	7396.3	20346.0
32	5.7650	4.4701	3.6	2.0	25.6	1715.5
33	9.5301	8.1936	14.7	7.2	414.6	3057.6
34	35.8952	34.8773	12.3	8.7	625.6	12912.9
35	18.9024	15.4735	8.9	4.4	142.1	5725.1
40	25.3589	15.1316	4.1	2.5	41.6	5636.7
42	7.4843	1.0348	1.5	1.0	5.7	382.0

* denotes slash fuels

Table J-2. Pre-fire fuel loading by ground and surface fuel components of the Eagles Cliff prescribed fire site.

	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" rotten	litter	duff	live	dead	Loading
3	.2596	1.3145	---	---	---	.5286	4.4467	.0022	.1070	6.6586
11*	.2144	10.7598	11.9315	37.1404	---	1.2721	6.2253	.0050	.2414	67.7897
12*	.0614	1.9625	1.7099	15.7023	---	1.9924	4.4467	.0011	.0535	25.9298
14	.0705	---	---	---	---	.4419	3.1127	.0072	.3513	3.9836
16	.0467	---	---	---	---	.6809	18.2313	.0096	.4697	19.4382
19*	.2731	6.7855	6.7567	47.0254	1.3112	2.5950	8.0040	.0013	.0649	72.8171
20	.0461	.1604	---	---	---	.6397	12.0060	.0052	.2564	13.1138
21	.0230	.4795	---	---	---	.0636	.4447	.0207	1.0135	2.0450
22	---	.1589	---	---	---	.2674	3.5573	.0203	.9950	4.9989
26	.1365	---	---	---	---	1.3075	16.4527	.0068	.3325	18.2360
27	.2729	.3168	---	---	---	.6551	13.7847	.0176	.8623	15.9094
28	.0454	---	---	---	---	.6831	4.8913	.0041	.2009	5.8248
29	.0223	1.3986	---	---	---	1.3870	21.7887	.0048	.2364	24.8378
30*	.3026	13.5324	4.2109	27.4719	---	.7534	24.9014	.0075	.0360	71.2161
32	.1159	.4843	---	---	---	.9032	4.0020	.0052	.2544	5.7650
33	.1623	.6457	---	---	---	.9032	7.5593	.0052	.2544	9.5301
34	.0921	.6415	1.1678	---	---	1.0332	32.9053	.0011	.0542	35.8952
35	.0467	---	---	1.2339	---	2.3317	15.1187	.0034	.1680	18.9024
40	.1790	.3116	---	---	---	1.6989	23.1227	.0009	.0458	25.3589
41	.1990	.1540	1.1214	16.1275	---	1.2562	13.7847	.0002	.0102	32.6532
42	.0217	---	---	---	---	.2213	7.1147	.0026	.1240	7.4843
43	.0223	.1620	---	---	---	.3292	2.6680	.0041	.2002	3.3858
44	---	.3286	---	---	---	.9083	3.1127	.0036	.1748	4.5280

* denotes slash fuels

Table J-3. Pre-fire loading statistics of the Eagles Cliff prescribed fire site.

		Loading by Ground and Surface Fuel Component (Tons/Acre)									
		Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Statistics		0.0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	duff	live	dead	Loading
Slash plots:											
	$\bar{x}$	.2129	8.2601	6.1523	31.8350	.3278	1.6532	10.8944	.0037	.0990	47.8436
	s	.1074	5.0292	4.3691	13.3940	.6556	.8077	9.4503	.0031	.0957	26.0192
	CV	50.47	60.89	71.02	42.07	200.00	48.85	86.74	82.96	96.72	54.38
	$s_{\bar{x}}$	.0537	2.5146	2.1846	6.6970	.3278	.4038	4.7251	.0015	.0479	13.0096
Range	Max.	.3026	13.5324	11.9315	47.0254	1.3112	2.5950	24.9014	.0075	.2414	72.8171
	Min.	.0614	1.9625	1.7099	15.7023	---	.7534	4.4467	.0013	.0360	25.9298
	PE	25.23	30.44	35.51	21.04	100.00	24.43	43.37	41.48	48.36	27.19
Non-slash plots:											
	$\bar{x}$	.0927	.3451	.1205	.9138	---	.8547	10.9529	.0066	.3216	13.6078
	s	.858	.4164	.3610	3.6950	---	.5604	8.7416	.0062	.3048	10.3401
	CV	92.52	120.67	299.60	404.37	---	65.57	79.81	94.72	94.76	75.99
	$s_{\bar{x}}$	.0197	.0955	.0828	.8477	---	.1286	2.0055	.0014	.0699	2.3722
Range	Max.	.2729	1.3986	1.1678	16.1275	---	2.3317	32.9053	.0207	1.0135	35.8952
	Min.	---	---	---	---	---	.0636	.4447	.0002	.0102	2.0450
	PE	21.22	27.68	68.73	92.77	---	15.04	18.31	21.73	21.74	17.43

where: Sample mean: $\bar{x} = \frac{\Sigma x}{n}$

Standard deviation: $s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$

Coefficient of variation: $CV = \frac{s}{\bar{x}}(100\%)$

Standard error of the mean: $s_{\bar{x}} = \frac{s}{\sqrt{n}}$

Range of maximum and minimum values obtained

Sampling error: $PE = \frac{s_{\bar{x}}}{\bar{x}}$

Table J-4. Post-fire fuel loading by ground and surface fuel components of the Eagles Cliff prescribed fire site.

	Loading by Ground and Surface Fuel Component (Tons/Acre)									
	Downed Woody Size Classes					Forest Floor		Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	duff	live	dead	Loading
3	.0236	---	---	---	---	---	2.2233	---	---	2.2463
11*	---	---	---	22.2807	---	---	---	---	---	22.2807
12*	---	---	---	5.0926	---	---	---	---	---	5.0926
14	.0235	---	---	---	---	.0674	.8893	.0001	.0016	.9819
16	---	---	---	---	---	---	---	---	---	---
19*	---	---	---	32.1946	---	---	---	---	---	32.1946
20	.0230	---	---	---	---	---	---	---	---	.0230
21	.0230	---	---	---	---	---	.8893	---	---	.9123
22	.0228	---	---	---	---	---	1.7787	---	---	1.8015
26	.0910	---	---	---	---	---	.8893	---	---	.9803
27	---	---	---	---	---	.0808	9.7827	---	---	9.8635
28	---	.1579	---	---	---	---	.4447	---	---	.6026
29	---	---	1.1316	---	---	---	16.0080	---	---	17.1396
30*	---	---	---	17.7148	---	---	---	---	---	17.7148
32	---	.1614	---	---	---	.1282	.8893	.0007	.0362	1.2949
33	---	.3229	---	---	---	.1042	.8893	.0004	.0197	1.3365
34	---	---	---	---	---	.1265	.8893	.0001	.0020	1.0179
35	---	---	---	---	---	1.1717	2.2233	.0007	.0332	3.4289
40	---	---	---	---	---	---	10.2273	---	---	10.2273
41	---	---	---	---	---	.4406	7.3370	---	---	7.7776
42	.0217	---	---	---	---	.1649	6.2253	.0008	.0368	6.4495
43	---	---	---	---	---	---	1.2932	---	---	1.2932
44	.0236	.1643	---	---	---	---	2.2233	---	---	2.4112

* denotes slash fuels

Table J-5. Second-year post-fire fuel loading by ground and surface fuel components of the Eagles Cliff prescribed fire site.

	Loading by Ground and Surface Fuel Components (Tons/Acre)								
						Forest Floor	Herbaceous Vegetation		Total Fuel
Plot No.	0-0.24"	0.25-0.99"	1.0-2.99"	3.0" + sound	3.0" + rotten	litter	live	dead	Loading
3	.0648	.2506	---	---	---	.6963	.0709	.0018	1.0844
11*	---	---	.6701	30.2227	---	.6457	.6759	.0933	32.3077
12*	---	.0523	.3430	3.5027	---	.2820	.3500	.0861	4.6161
14	.0902	.3663	---	---	---	.5721	.3026	.0163	1.3475
16	.0432	.3008	---	---	---	.5383	.1966	.0106	1.0895
19	.0891	.4134	.3387	9.6063	---	1.1145	.5070	.0699	12.1389
20	.0220	.2045	---	---	---	.6394	.0616	.0033	.9308
21	.0226	.1570	---	---	---	.2244	.2859	.0331	.7230
22	.0216	.1506	---	---	---	1.3348	.3397	.0285	1.8752
26	.0874	.1521	---	---	---	.3403	.5308	.1530	1.2636
27	.0661	.3578	---	---	---	.4017	.1080	.0091	.9427
28	.1354	.1047	.3430	---	---	.2072	.2635	.0305	1.0843
29	.0220	.4601	---	---	---	.1205	.9227	.0237	1.5490
30*	.0437	.2534	---	23.5593	---	.7089	.2204	.0542	24.8399
32	---	.2008	---	---	---	.1579	.0364	.0009	.3960
33	.0216	.4015	.6580	---	---	.9836	.1463	.0079	2.2189
34	.1128	1.3084	.3430	---	---	.5876	.3309	.0383	2.7210
35	.0891	.8267	1.0160	---	---	2.0300	.2332	.0270	4.2220
40	.0437	.1521	.3322	---	---	1.9492	.0933	.0050	2.5755
41	---	.3041	---	---	---	2.3978	.0111	.0003	2.7133
42	.1748	.8110	---	---	---	2.4321	.1741	.0094	3.6014
43	.0434	.2519	---	---	---	.5842	.0549	.0046	.9390
44	.0458	.3718	---	---	---	2.5971	.0195	.0005	3.0347

* denotes slash fuels

Table J-6. Hourly Fuel Moisture and Weather Data During the Eagles Cliff Prescribed Burn (October 3-4, 1975).

Date	Time of Day	Weather Variables: Temperature °F	Relative Humidity percent	Wind Velocity mph	Fuel Moisture (%) by Surface Fuel Components: 0.0-0.24"	0.25-0.99"	1.0-2.99"	Herbaceous Vegetation Dead
10-3-75	0800	49	---	3-5	---	---	---	---
	0900	52	24.5	< 3	10.0	14.0	15.0	9.5
	1000	62	20.5	< 3	8.0	10.0	13.0	7.0
	1100	68	15.0	< 6	7.0	9.0	12.0	6.0
	1200	71	14.0	6-7	6.0	9.0	10.0	6.0
	1300	74	13.0	5-6	6.0	8.0	9.0	4.0
	1400	76	9.0	6-7	4.0	6.0	8.0	3.0
	1500	74	10.0	8-9	4.0	6.0	8.0	3.0
	1600	76	10.0	4-5	---	---	---	---
10-4-75	0800	52	---	8-10	---	---	---	---
	0900	56	---	8-9	---	---	---	---
	1000	60	---	8-10	7.0	9.0	12.0	6.0
	1100	62	---	8-9	7.0	9.0	12.0	6.0
	1200	68	13.5	8-9	6.0	7.0	10.0	5.0
	1300	71	12.4	9-10	5.0	6.0	9.0	5.0
	1400	72	---	9-10	4.0	6.0	8.0	3.0
	1500	---	---	---	---	---	---	---
	1600	---	---	---	---	---	---	---

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